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Abstracts Bulletin

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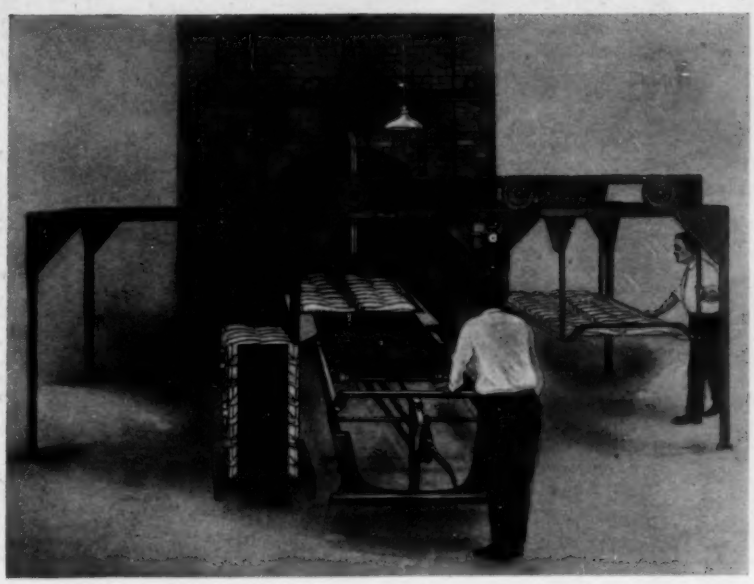

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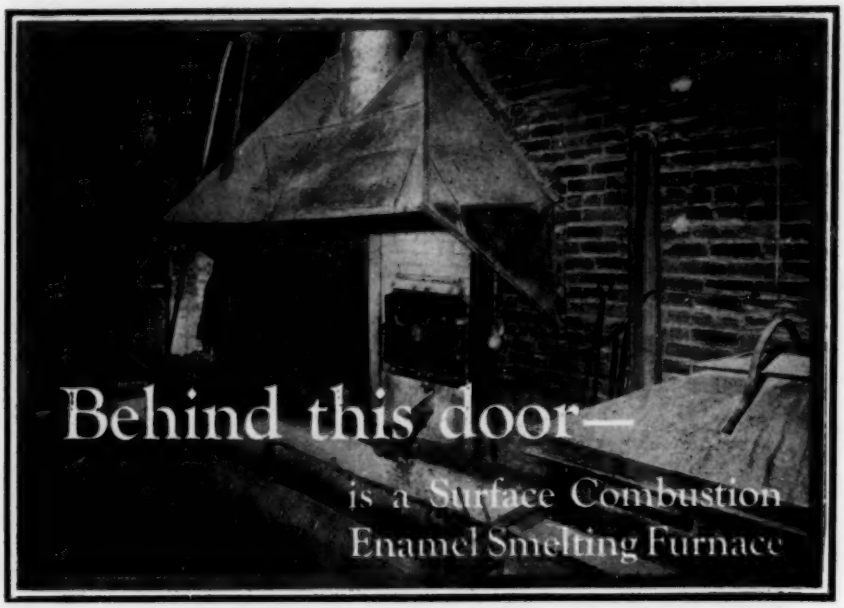

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ORIGINAL PAPERS

THE USE OF BORIC OXIDE IN GLASS-MAKING

By W. E. S. Turner[1]

ABSTRACT

Boric oxide behaves differently from other glass-making constituents in that the variation of physical properties is not progressively continuous with a variation in composition. With increase of boric oxide content in sodium borosilicate glasses, the refractive index (μ_D) rises to a maximum as also does the annealing temperature, while the coefficient of thermal expansion reaches a minimum and then rises. The durability, or resistance to water and hydrochloric acid reaches a maximum when the glass contains about 12% of boric oxide and subsequently falls off very rapidly. There is, accordingly, a limit to the usefulness of boric oxide in glass.

Introduction

The advantages attending the use of boric oxide in glass-making, whether as borax or boric acid, are widely known although less widely understood. It is not only in the manufacture of optical glasses, scientific, illuminating and heat resisting glassware that its importance has been recognized but it has also had its application in the preparation of bottle glass and of glass for tableware.

Advantages in General.—The functions which recommend boric oxide in these different classes of glassware are several. In optical glasses specific influences on the value of the refractive index and dispersion due to the oxide are made use of, while increase in durability is also gained.

[1] Recd. Feb. 12, 1924.

For scientific, illuminating and heat-resisting glasses the two most important properties which boric oxide bestows are an enhanced durability and a diminished coefficient of thermal expansion. A reduction in the viscosity of the molten glass is not the least important of the effects of this oxide, an effect of much value in glass-making practice.

This fluxing effect is the main reason for the employment of boric oxide or borax in the production of sealing-in glasses, for enamels, and generally as a medium for the application of pigments to glass. For the same reason, no doubt, it has found frequent use in some of the smaller glasshouses in England in which glass is melted from cullet, to which, in some cases, a small quantity of an alkaline salt, borax in particular, is added.

The object of using it in the production of colorless glass in tank furnaces does not appear yet to have been satisfactorily explained. We have found no evidence of any favorable influence excited by it in the decolorizing process. We have found, however, from our own experiments in this Department, that even small amounts, less than 1% in the glass, may quite distinctly influence the viscosity of the molten glass while a definite enhancement of the durability simultaneously occurs. That this last statement is a fact is proved in the case of potash- and potash-soda-lead oxide glasses by the experiments of Hodkin and Turner.[1]

Effect of Boric Oxide not Continuously Additive

The question as to whether or not boric oxide continues to exercise its valuable functions in a glass in direct proportion to the amount present has been obscured in the past partly by general experience and partly by the deductions associated with the various additive rules deduced by Schott, Winkelmann and others. It certainly is the general experience that a continued increase in the proportion of silica in a glass produces a continuously increasing viscosity, a diminishing thermal expansion and an enhanced resistance to corrosion; and the same continuity of change in physical properties with variation of composition also appears to be true of many other well-known constituents of glass.

It was pointed out however, by Zschimmer[2] in 1905, that when boric oxide was added to potassium silicate in continuously increasing proportions, the refractive index (μ_D) rose to a maximum value and then diminished. Recently it has been proved that a similar reversal occurs in several properties. Thus, we have shown[3] that not only does this apply to the refractive index of sodium borosilicates, but also to the density, the thermal expansion, the annealing temperature and the durability. These

[1] *Jour. Soc. Glass Tech.*, **4**, 121 (1920).

[2] *Zeitsch. Elektrochem.*, **11**, 629 (1905).

[3] English and Turner, *Jour. Soc. Glass Tech.*, **7**, 155 (1923).

reversal effects are of the utmost importance both technically and in industry; for it has been demonstrated that a reduction of thermal expansion or of liability to corrosion by increasing the percentage of boric oxide only holds good up to a certain point beyond which the thermal expansion rapidly becomes greater as also the extensiveness of corrosion by water and chemical agents. Any attempts, therefore, to improve heat-resisting glasses or chemical glassware by the introduction of ever-increasing percentages of boric oxide are doomed to failure; there is a limit beyond which deterioration, not improvement, occurs.

Effect of Boric Oxide on Resistance to Weathering

So far as weathering and resistance to chemical agents are concerned, boric oxide as an enhancer of resistance is something of an anomaly. Dralle[1] points out that the durability of a glass may be judged, in a rough and ready way, by the relative solubilities in water of the constituent oxides. Boric oxide, however, provides an exception to the rule. It is readily soluble in water and yet when present in commercial glasses, it has been found to enhance, very greatly in many cases, their resistance to the attack of water and of chemical reagents. The explanation of this phenomenon has generally been sought in the assumption of the formation of a class of compounds known as borosilicates, or, alternatively, in the suggestion that boric oxide substitutes silica in the silicates, the increased durability being actually due to an increase of free silica. Both theories appear to the author to lack positive evidence to support them.

Indications of the unreliability of boric oxide as a never-failing source of resistance to weathering have not been wanting in the past but they have not been widely known. There is no doubt that many old enameled glasses have suffered through the use of borax as the fluxing medium whereas those in which lead silicate has been employed have withstood the ravages of time. Schaller states that boric oxide added to sodium silicate at first diminishes the attack by water but later increases it. Sullivan and Taylor, in their account of Pyrex Glass, stated that they found a limit to the usefulness of boric oxide as beyond a certain percentage the glass containing it rapidly fell away in durability.

So far as the general problem of durability is concerned an exhaustive experimental study of the behavior of a large number of commercial chemical glasses led the writer with J. D. Cauwood[2] to the conclusion that, "Boric oxide increases the resistance of glass towards water, although it is probable that beyond a certain value (about 12 molecules per 100 molecules of silica), this effect declines. Boric oxide weakens the resistance of a glass towards alkali and hydrochloric acid."

[1] "Die Glasfabrikation," 1911, p. 85.

[2] *Jour. Soc. Glass Tech.*, **2**, 233 (1918).

Recently it has been found possible to test this conclusion in a more direct manner, and based on work carried out in this laboratory by Miss V. Dimbleby, evidence that it is substantially true has been forthcoming.

Two series of glasses containing the oxides, soda, boric oxide and silica have been examined, one series containing approximately 20 and the second 10% of sodium oxide as constant quantities, the two variables being the silica and the boric oxide. Tests of the durability were made on grains of glass of 20- to 30-mesh by a method which has previously been described in a paper from this laboratory, boiling water or hydrochloric acid of 20.24% strength being the reagents and the time of their action one hour. The results are set out in Tables I and II.

TABLE I

THE ACTION OF BOILING WATER ON GLASSES OF THE SERIES CONTAINING APPROXIMATELY 20% Na_2O

Percentage composition of glass			Percentage loss of weight in water	Percentage Na_2O (total alkali) liberated
SiO_2	Na_2O	B_2O_3		
79.81	19.26	...	2.34	2.11
74.22	19.76	4.46	0.48	0.16
71.56	18.76	8.28	0.27	0.06
68.33	18.95	11.37	0.42	0.04
64.72	19.95	14.45	0.37	0.07
61.28	18.93	18.84	0.59	0.14
50.04	20.36	28.83	8.70	2.25
35.22	23.71	39.99	39.83	11.56
32.23	23.08	43.70	52.67	14.74

TABLE II

THE ACTION OF BOILING WATER AND HYDROCHLORIC ACID ON GLASSES OF THE SERIES CONTAINING APPROXIMATELY 10% Na_2O

Percentage composition			Percentage loss in wt. in water	Percentage Na_2O liberated	Percentage loss in wt. in HCl
SiO_2	Na_2O	B_2O_3			
74.91	11.26	12.45	0.13	0.004	0.09
70.75	9.79	18.71	0.44	0.07	0.67
67.18	10.13	21.81	1.55	0.36	2.73
61.94	11.19	25.82	4.67	0.89	32.49
57.87	9.55	31.26	12.80	2.42	41.01
52.11	10.34	36.17	30.82	5.50	49.00

It will be noted from Table I, that a minimum corrosion value occurs (based on the alkali liberated) when the glass contains approximately 11–12% B_2O_3. In other words, the maximum durability is reached at this point. A very rapid decline in durability occurs between 18–28% of boric oxide.

The tests with hydrochloric acid are not yet complete but the results so far obtained are parallel to those with water, maximum corrosion being

obtained at the same point in the composition as is the case with water.

In the second series, containing approximately 10% of Na_2O, the corrosion continuously increases from the first glass examined. That glass, however, already contains 12.45% of boric oxide. It appears to be more durable than any number of the series in Table I and it may well be that maximum durability occurs when the glass contains approximately 12%. The corroding action of hydrochloric acid is parallel to that of water.

We thus have direct evidence that boric oxide improves the durability of a glass only up to a certain point and there is strong probability that approximately 12% in the glass marks its most useful limit.

DEPARTMENT OF GLASS TECHNOLOGY
THE UNIVERSITY
SHEFFIELD, ENGLAND

THE DEVELOPMENT OF TRANSPARENT COLORED GLASS IN AMERICA FOR GOGGLE PURPOSES[1]

By Edwin L. Hettinger

Introduction

ABSTRACT

Prior to the World War all of the goggle glass was imported from abroad. Necessity made us develop it in this country. Today all of the colors used for goggles are made near Pittsburgh. Glass is blown into large balls which are cut into strips and then cut into circles. Average thickness of glass is 2 mm. Average diameter of balls, 36 inches. Shades are graded into light, medium and dark. Colors are amber, smoke, fieuzal, amethyst and blue.

Historical

The commercial production of colored glasses forms an important branch of glassmaking, although most of the coloring agents have been in use many years. Some early colors were produced by the Chinese and the Egyptians with whom the honors are about even on the priority of glassmaking.

While some colored glass was made in the United States prior to 1914, practically none of it was fit for use in ophthalmic, eye protection or technical industries. Several such glasses were tried but found to be of little value commercially. The glass directories listed 48 companies manufacturing illuminating ware, but very few of them had men familiar with transparent colors. The large users of these glasses urged the production of colored glasses that would not be prohibitive in price.

To the average individual the production of colored glass has not seemed to be a problem; even scientific men did not give it special attention. Thorpe, Knapp, Linton and Benroth did not include it in their classification.

Classification

The first division would consist of pot colored glasses and stained glasses. While stained glass and glass enamel process have been wonderfully developed and improved, they still deserve a great deal of consideration.

Pot colored glass will be divided into the following: Transparent, Translucent, Opalescent, Luminous, Iridescent and Opaque.

Transparent colors are used for ophthalmic lenses, eye protectors, railroad signals, motor cars, light houses, ray filters, color processes, church windows and many other commercial and technical uses. Translucent glasses were easier to produce. The more colors the glassmaker produced the more could the decorator vary his shades and colors.

Luminous and "one way" glass was of some value, but limited in its uses. This was produced in small quantities.

Producers of illuminating glass have made wonderful progress in iri-

[1] Presented at the Atlantic City Meeting, Feb., 1924 (Glass Division).

descent ware. The number of tints and shades have been increased in endless variety of color. These manufacturers also produce the opaque.

Industrial Developments since August, 1914

To find glass manufacturers producing transparent colors willing to develop transparent colored glass of uniform shade and density was a problem. Very few employed a ceramic chemist. Firms which had extensive laboratories did not have the shop organization to balance.

By the fall of 1914 the United States market was very short of these glasses. During the early part of March, 1915, fairly good transparent colors were being produced, but within a few months this glass showed signs of decay or weathering. The glassmaker knew it better as "sweaty glass."

The difficulty was in using a batch which would melt at too low a temperature. This low temperature was employed in order to save the pots. The batch did not produce a staple glass free from lines and striae. With the production of better pots, better balanced batches and more careful workings, most of the troubles were eliminated. Before some of the plants had pyrometers installed, their workers guessed at the temperature—and the result was a guess in colors. Most of the colored glasses are now brought up to a melting temperature of 2450°F, with a working range of about 1800° to 1900°F.

The glass blowers employed were from window glass houses. Sometimes the glasses were blown into cylinders as is done in ordinary window glass, and the flattening and annealing also were the same as in window glass practice.

Process

When the batch is blown into balls a different gathering is required. These balls average about 36″ in diameter. Some of the balls weigh 18 to 20 lbs. The neck, good for cullet, weighs from 4 to 6 lbs., leaving about 14 to 15 lbs. of glass fit for commercial use. The shop would get about 100 to 110 balls out of a pot with a ton capacity.

For some colors and some batches a closed pot is more desirable. The open pot is used whenever possible on account of pot and fuel cost. A great deal of skill was required to get uniform thickness of glass in the large balls. Operators were developed to such a degree of skill that they could blow free hand, balls of almost uniform diameter and shape. One firm tried to blow them into paste molds but this was too slow and expensive and did not improve the quality.

From these balls the goggle lenses are cut in various ways depending on the ingenuity of the operator in charge. Special annealing is not required.

The circles are now called mi-coquille lenses. As the surfaces are practically concentric, they answer the purpose for eye protection—not correction. The coquille lenses are cut from balls 12 to 18 inches in diameter. These lenses are not very desirable on account of the irregular surfaces and glass defects.

The Industry

Today amber, smoke, fieuzal, amethyst, blue, green and other colors are produced in satisfactory shades and colors. E. E. Shreiner names 104 glasses in his work on colored glass, most of which could be grouped into about ten combinations of color.

All of the glass must average from $1^1/_2$ to 2 millimeters in thickness. The shades range light, medium and dark. The light shade is divided into 1 and 2, the medium into 3 and 4, the dark into 5 and 6. Extra dark shades such as 7, 8, 9 and 10 are for industrial or special purposes.

The colored goggles on the local market are now fitted with American made glass. One Pennsylvania firm made more than a million pairs of colored goggles for the Allied and United States Armies. These goggles are used for eye protection of truck drivers, aviators, ambulance drivers, lookouts on ships, anti-air craft corps, industrial workers in military repair shops, troops in snow clad countries, ship builders, welders, riveters and every conceivable occupation.

The subject of eye protection has become so important that codes covering the variety of glasses for the several industrial uses have been adopted.

The development of ophthalmic glass for eye correction has had this same sort of development, prompted at first by necessity and now continued on a large production basis.

To the glassmaker who takes up the subject scientifically and produces glasses with known power of absorption and transmission on a commercial basis the field is unlimited.

The coloring agents were easy to secure; the big secret was a batch of balanced chemical composition. Formulae were readily obtained, but the old glassmaker could not understand why iron gave an orange color with one batch and dull green with another. Oxidizing and reducing flame meant nothing to him—he usually wanted heat and the pots to stand the heat.

TYPE OF FORMULAE USED

Batch Used for Medium Amber	
Sand	600 lbs.
Soda Ash	200 lbs.
Barium Carbonate	125 lbs.
Calcium Carbonate	48 lbs.
Nitrate Soda	48 lbs.
Red Iron Oxide	65 lbs.
Manganese	48 lbs.

For fieuzal—a yellow green—they used bichromate potash (8 oz.) and black oxide nickel (4 oz.) to 100 pounds of the base batch.

BROWN: Nickel and Mixture Manganese and Iron Oxide

AMBER: Sugar, Coal, Carbon, Red Oxide Iron or Sodium Uranate, Charcoal, Saltpetre, Salt, Charcoal, Tartar, Calcined Oats

SMOKE: Combination of Red Iron Oxide, Manganese, Copper or Black Oxide Nickel

WHITE OR OPAL: Phosphate of Lime, Talc, Cryolite, Alumina or Zinc Oxide, Calcium Fluoride

BLACK: Cobalt Oxide, Nickel Oxide, Iron, Platinum, Iridium, or Basalt, Iron Ores

YELLOW: Uranium, Carbon in various forms, Potassium Antimoniate, Sulphur, Ferric Oxide, or Silver Nitrate, Cadmium Sulphate, Vanadium, Cerium

RED OR RUBY: Red Oxide Copper, Selenium, Gold Chloride, Purple of Cassius, or Antimony Oxysulphide, Manganese, Oxide Iron

AMETHYST OR VIOLET: Manganese Oxide or Nickel Oxide

BLUE: Cobalt Oxide, Nickel Oxide, Iron Oxide or Copper Oxide

GREEN: Chromium Oxide, Black Oxide Copper, Red Oxide Iron, Vanadium

Rare earths have not been considered in this paper. To those interested the author suggests J. Newton Friend's "Inorganic Chemistry," Volume IV, on "Aluminium and Its Congeners—including Rare Earth Metals."

READING, PA.

A NOTE ON EARLY OPTICAL GLASS MAKING IN THE UNITED STATES[1]

By Henry H. Blau

ABSTRACT

The manufacturing process employed and the products obtained in the early work on optical glass in the United States, are described in detail.

Contrary to general belief, optical glass was manufactured in the United States as early as 1888. After our entrance into the World War, no less reliable a periodical than the *Literary Digest* published the statement, "Not an ounce of optical glass was made in the United States before the war." However, in April, 1917 the investigations of the National Research Council revealed that such information was incorrect, and Arthur L. Day representing that body states in his paper, "Optical Glass and Its Future as an American Industry," "It is to the credit of the elder Macbeth of the Macbeth-Evans Company, that the first attempt to manufacture in this country glass of high optical quality was undertaken in the early nineties and a number of creditable lenses, some of considerable size, stand as monuments to the success of this effort." Under the belief that a brief review of this work would be of general interest, information concerning this early venture was collected and the present paper undertaken.

John A. Brashear, the noted manufacturer of astronomical apparatus, was a close friend of George A. Macbeth. Through Dr. Brashear, Mr. Macbeth became interested in the superior quality of glass imported from abroad and used in the Brashear Laboratories. This interest became an enthusiasm, and in 1888 Mr. Macbeth decided to attempt the manufacture of optical glass. At that time he was operating a factory known as the "White House," located on the South Side in Pittsburgh, where he produced lamp chimneys and some glass dials for watches, from a lead glass of a quality superior to that previously produced. A few blanks were pressed from it for Dr. Brashear. It was not until 1889, however, that the commercial manufacture of optical glass was really undertaken, and a plant for this particular purpose constructed in conjunction with his new works at Elwood, Indiana under the supervision of T. F. Harnack, now of the H. L. Dixon Company but formerly superintendent of the Macbeth Factory at that place.

In accordance with the custom of those days, this plant was given a name, "The French House," derived from the nationality of its manager, Eugene Field. Mr. Field came from a line of optical glass makers, and had followed this work in Europe with his father, the maker of the Lick Observatory lens. With his knowledge of foreign methods and Mr. Macbeth's of the American glass industry, the proper materials were obtained

[1] Presented at the Atlantic City Meeting, Feb., 1924 (Glass Division).

and methods established for the production of optical glass of the extremely high quality required for scientific apparatus.

The purest materials available were used in the making of this glass. The sand was shipped in barrels to Indiana from the Berkshire Hills of Massachusetts. The sodium carbonate was of the grade known as Sullivan ash 58% and was imported from England in casks. The potash and barytes were obtained from Germany in similar containers, and the niter from Chile. The litharge was purchased domestically until its manufacture was undertaken at Elwood to obtain material of satisfactory purity. The soluble materials were purified by dissolving in water, removing the scum and crystallizing them out of the solution after decantation into an evaporator. Satisfactory barrelled borax was obtained in this country. These materials were introduced into the glasses in varying proportions.

The inability to locate all of Mr. Macbeth's records together with the jealous secrecy of those times precludes a detailed account of the development of the compositions used. It is known, however, that crowns, flints, barium crowns and barium flints were made. Batches for these glasses together with corresponding cullet were filled into a one-pot furnace.

The old "French House" had but a single one-pot furnace, a deep-eyed one, fired by natural gas. It consisted of a chamber ten feet square inclosed by refractory brick walls eighteen inches thick and four feet high, surmounted by the ordinary crown and stack. The bench was built up of the glass house refractory brick used in those days. The pot was placed in the furnace so that its rear wall abutted on the eye. These pots, as well as the clay molds used in reforming the glass, were manufactured by the Willetts Company, which then maintained a pot house at Elwood, Indiana. They were covered, 22 inches in diameter and accommodated a metal depth of about 16 inches. They were placed in the furnace and gradually heated up to melting temperature when they were charged with a mixture of batch and cullet.

The manufacturing process was much like that of the present day. After the contents of the pot were completely fused, a preheated clay stirring rod was introduced through the pot mouth. An iron handle supported by chains from a roof truss was fitted inside the clay stirrer, and with this arrangement the glass was stirred with a circular motion for from six to eight hours. When proofs indicated that the glass was homogeneous, the gas fire was slowly turned down and the stirring continued until the glass became too stiff to permit it. All openings to the furnace (including the stack) were then sealed, the gas turned off, and the furnace and its contents allowed to cool gradually.

When completely cooled the pot was removed from the furnace and

the clay broken away from the glass. The fragments of glass as well as the imperfect larger pieces were discarded as cullet, and those larger ones found to be free from imperfections, were subjected to further treatment.

Pieces of a weight approximating that desired in the finished article were placed in chalk-covered clay molds whose shapes were plane, convex or concave depending on requirements. These molds containing the glass were placed in a reheating furnace eight feet square on the inside, bounded by eighteen-inch walls and fired from two opposite sides with natural gas. Heating was continued until the glass had softened sufficiently to conform to the shape of the mold. Then, after sealing the oven tightly, the gas was turned off, and the glass cooled in the oven very slowly. The cooling rate depended on the size of the pieces, the larger ones requiring as high as four days.

Those pieces which had not melted down sufficiently were placed in the remelting furnace again and the others were tested for freedom from strain with a polariscope and their densities checked. Some of the smaller pieces were shaped by reheating and placing in a press. These had to be subsequently annealed in a kiln.

"The French House" was provided with small grinding and polishing units so that test pieces were made on the ground. This testing work was sufficiently well correlated with the composition of the glass that Mr. Macbeth was able to obtain lens blanks to replace several imported ones broken in grinding, when Dr. Brashear was constructing the six-inch lens system for the telescope of the University of Tokio.

This was but one of the notable installations in which the optical glass produced in "The French House" was used. Blanks made at Elwood were also used by Dr. Brashear:

1. For the photographic corrector in the twelve-inch objective for the Dudley Observatory of Albany, New York.
2. For a triplet for the Dr. Gill National Observatory of South Africa.
3. For the six-inch aperture lens for the astronomical photography camera of Princeton Observatory.
4. For the two-inch spectrographic lens of the University of Chicago.
5. For a range finder objective manufactured March 15, 1898.
6. For a six-inch lens of 400 feet focal length for the U. S. Army Signal Corps.

Dr. Hastings of Yale University tested Macbeth prisms in January, 1892 and at that time found a crown one to have a dispersion of 0.0188 for the B and C lines. The same year he used a flint glass in making a 9.25-inch objective for that Institution. Bausch & Lomb and the Eastman Kodak Company also purchased some glasses, including a lead one of the high density of 3.58. During the International Exposition held in Chicago

in 1893, Mr. Macbeth was awarded for his exhibit of optical glass-discs, a diploma, which reads:

"Optical Glass: In this exhibit are shown disks of Crown and Flint Glass of the following diameters: 3, 4, 5, 6, 8, 12, 16 and 23 inches, of which one, 12 inches is of Flint and one of Crown. The specific gravity of the Flint is 3.50 and of the Crown 2.51. The two latter together with a $5^1/_2$ Flint prism are the first of their respective sizes of American manufacture ever exhibited. In freedom from bubbles and stones they are of a high grade."

All of this goes to show that optical glass of high quality was manufactured in the United States many years ago on a successful basis. In spite of the perseverance of those engaged in the work the effort was doomed to commercial failure, because the big users could not be weaned away from the foreign sources of supply and no market could be found for the smaller pieces. The manufacture was finally abandoned for these reasons.

CHARLEROI LABORATORIES
MACBETH-EVANS GLASS COMPANY

FACTORS AFFECTING THE WARPAGE OF SHEET IRON AND STEEL IN ENAMELING[1]

By R. R. Danielson, T. D. Hartshorn and W. N. Harrison

ABSTRACT

The effects upon warpage of different methods of cleaning the metal, durations of firing periods, scaling practices, gages of metal, types of enamel, etc., are studied. Test pieces 16 x 16 inches are employed, several commercial enameling irons and steels being used and compared. Warpage is determined by obtaining the areas on five evenly spaced, vertical planes, parallel to one edge of the test piece, included between a flat, horizontal base plane and the contour of the test piece resting thereon. The average of the five areas in square centimeters is used to express numerically the degree of warpage.

The conclusions are: (*a*) A wide divergence between the expansivities of the enamel and the metal base induces warpage, (*b*) there seems to be less tendency for the scaled metal to warp than for that cleaned chemically, (*c*) thin metal is more sensitive to the factors affecting warpage than thicker metal, (*d*) sudden, irregular cooling induces warpage, (*e*) tendency to warpage is reduced by properly supporting the ware during firing and cooling.

Introduction

The warping or buckling of sheet iron and steel during the enameling process is a cause of considerable loss and worry to the manufacturers of flat ware, such as stove parts, table tops and signs. An investigation was undertaken by the Bureau of Standards, in coöperation with the Enamel Division of the American Ceramic Society, in order to obtain definite information on this important subject.

The problems bearing upon warpage may be divided into two general classes; those which are essentially metallurgical, and those which are related to the practices and materials used in application of the enamel. The use of only such conditions as could be practically reproduced with the equipment ordinarily found in enameling plants was planned for this investigation, and consequently, although factors of both classes are involved in many steps of the enameling process, the investigation was directed primarily upon those of the non-metallurgical type, except that iron and steel from several sources were used, and their warpage compared. The effects of various methods of cleaning the metal, methods of scaling, time of firing, and other factors having a bearing on this problem were also studied.

Materials

The sheet iron and steel used in this investigation were received from three manufacturers, and are designated as metals A, B, and C. All of the sheets received from each manufacturer came from the same melt,

[1] By permission of the Director, Bureau of Standards. Presented at the Atlantic City Meeting, Feb., 1924. (Enamels Division.)

with the exception of lot B, which contained an extra set from a different melt, designated as metal B′. Metals A and C are commercial enameling irons, while B and B′ are commercial steels. Metal B is a rephosphorized basic, open-hearth steel, and B′ is a low phosphorus basic, open-hearth steel.

Each manufacturer furnished sheets of rolled stock, 96 by 32 inches, in both 18 and 22 gages. There were 12 sheets each of metals A, B and C, six in each gage. Metal B′, however, was furnished in only 18-gage, giving a total of 42 sheets from all sources. The sheets were numbered A-1, A-2, ——, B-1, B-2, etc. Each of these sheets was cut into 12 plates, 16 by 16 inches, which were numbered as illustrated in Fig. 1, making a total of 504 test plates. Each plate was stamped with its number for easy identification. Thus plate B-10-9, shown in Fig. 2 was cut from position 9 (Fig. 1) of sheet B-10.

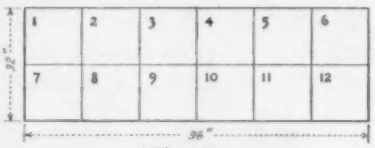

FIG. 1.

The system of numbering the plates was the same for each sheet in order to trace the history of each test plate, not only with regard to its location in each sheet, but also as to the method of handling the individual plates.

Three ground and three cover enamels, covering a wide range of expansivity, were prepared according to the compositions in Table I. The batch compositions are shown in Table II.

In order to obtain uniform results, a sufficient quantity of each enamel was obtained from a 300-pound batch which had been melted in a commercial smelter. All were milled in 100-pound lots to pass a 60-mesh sieve for the ground coats and 80-mesh for the cover. The ground and cover enamels designated as L (low expansivity) have a coefficient of expansion decidedly below that of iron and steel, which is usually given as 12×10^{-6} to 13×10^{-6} per °C (linear), and are comparatively refractory. Enamels M (medium expansivity), which are more fusible, have a coefficient of expansion more nearly approximating but still lower than that of the metal, while enamels H (high expansivity) have an expansivity approximating that of iron and steel and are fusible at comparatively low temperatures.

Procedure

The enamels were applied by dipping, each plate being ground-coated on both sides and given two coats of the cover enamel on the numbered or top side. It should be noted that some plates were later given third and fourth applications of the cover coat as more than two are not unusual in sign work.

The plates were burned in a two-burner, gas-fired muffle furnace, having a muffle chamber 20 x 48 inches. Temperatures were measured with a

platinum-platinum rhodium thermocouple which extended 8 inches within the muffle. The standard support used in firing consisted of seven parallel rows of eight points each, composed of a heat-resisting alloy. This arrangement gave each plate uniform support. Each piece was removed from this rack with a steel fork and allowed to cool upon a cast iron grid or cooling table of the open webbed pattern.

TABLE I

ENAMELS

	Theoretical melted compositions						
Enamel	Feldspar, per cent	Boric oxide, per cent	Cryolite, per cent	Sodium oxide, per cent	Fluorspar, per ent	Cobalt oxide, per cent	Observed linear coefficient of expansion
Cover L	60	21	12	2	5	.	9.3×10^{-6}
Cover M	60	15	12	8	5	.	11.7×10^{-6}
Cover H	60	9	12	14	5	.	12.4×10^{-6}
Ground L	60	21	11	3	4	1	9.5×10^{-6}
Ground M	60	15	11	9	4	1	11.2×10^{-6}
Ground H	60	9	11	15	4	1	12.3×10^{-6}

TABLE II

ENAMELS

	Batch compositions for 100 lb. melted frit							
Enamel	Feldspar, per cent	Boric acid, per cent	Borax, per cent	Cryolite, per cent	Sodium nitrate, per cent	Soda ash, per cent	Fluorspar, per cent	Cobalt oxide, per cent
Cover L	60	37.2	..	12	5.5	..	5	.
Cover M	60	3.0	36.3	12	5.5	..	5	.
Cover H	60	..	24.6	12	5.5	13.6	5	.
Ground L	60	37.2	..	11	5.5	1.7	4	1
Ground M	60	..	41.0	11	6.1	..	4	1
Ground H	60	..	24.6	11	5.5	15.3	4	1

MILL ADDITIONS

Cover enamels		Ground enamels	
Frit	100.0	Frit	100
Clay	5.0	Clay	6
Tin Oxide	7.0	Borax	1
Magnesia	0.5	Water	55
Water	55.0		

The investigation was divided into three sections, a different factor being varied in each. In Section A, different methods of preparing the plates for enameling were used. To differentiate between the two used for removing grease, the terms "cleaning" and "scaling" are employed, the former applying to the use of an alkaline cleaning solution and the latter to removal by a short heat treatment.

Plates 7–12 (Fig. 1), of the first three sheets of each metal, including both 18 and 22 gages, were cleaned, while plates Nos. 1–6 of these sheets were scaled by heating in a furnace at 750°C (1382°F) until the plates

reached a dull red color. This selection of specimens insured an equal distribution of corner and middle plates, thus equalizing possible warping tendencies due to position in the large sheet as it was rolled. All were pickled in hot 5% hydrochloric acid, rinsed in water, immersed in a weak soda solution, dried, dipped, and the enamel burned at 875°C (1607°F).

In Section B an attempt was made to determine the effects of variations in firing temperature, 825°C (1517°F), 875°C (1607°F), and 925°C (1697°F) being used. Plates Nos. 5, 6, 8, 10, 11 and 12 (Fig. 1) of the remaining three sheets of each metal were selected and found to be suffi-

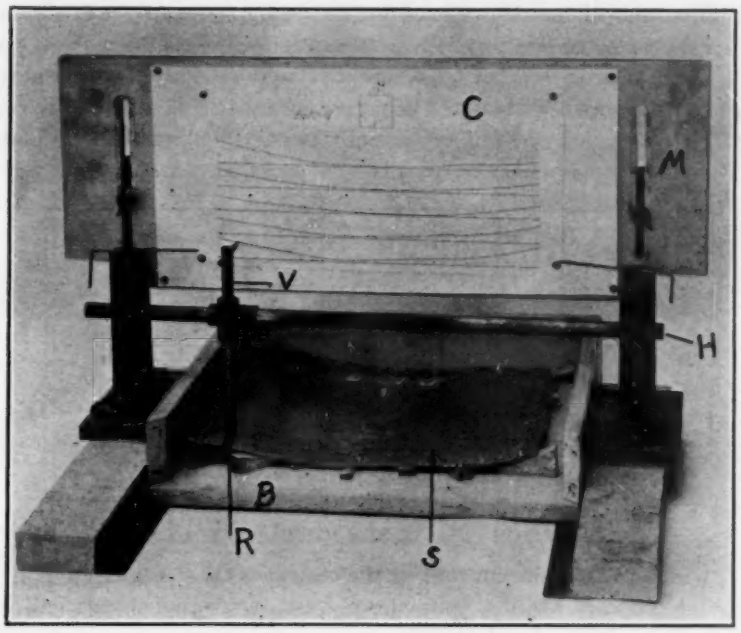

FIG. 2.—Warpage recording device. (The warpage of the test plate shown is 19 units.)

ciently free from grease so that they could be pickled without being cleaned or scaled. Only the enamels of medium expansivity were used on these trials.

Section C is devoted to the determination of the effect of variation in temperature and length of time of scaling and in the types of supports used for cooling. All the plates not used in the two previous sections were heated at 850°C, 900°C or 950° (1562°F, 1652°F or 1742°F) for periods of two, four and six minutes, respectively, at each temperature. During the scaling operation, a rack of four points, arranged at the corners of an 8-inch square was used. Alternate pieces were allowed to cool upon the

same rack or upon the cooling grid. They were then pickled and coated with enamel of the L, M or H type, only the grid being used for support in the subsequent cooling.

Calculation of Warpage

The warpage of the plates subjected to the various treatments was graphically recorded after the ground coat and also after the second cover coat applications. Those receiving four covers were measured after the final coating, and the specimens in Section C, which received special scaling treatment, were measured before being ground-coated.

A photograph of the device used for recording the warpage is shown in Fig. 2. A test plate S is placed, concave side up, on the base B, movable from front to rear on iron tracks, where it is supported rigidly in its natural position with wooden wedges. The recording chart C is attached to board M, which slides vertically upon upright bars. The warpage of plate S is recorded upon the chart by means of a pencil attached to the vertical

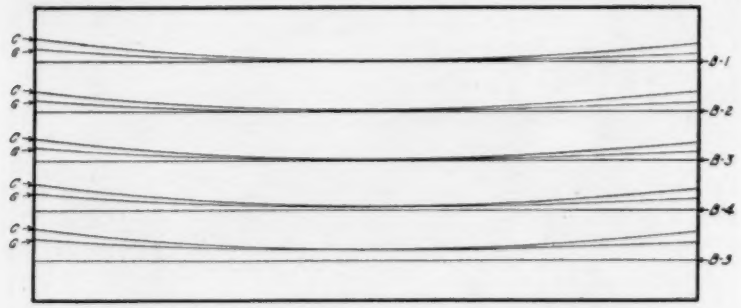

FIG. 3.—Sample chart, showing typical warpage record.

rod V, which follows the contour of the test piece as V is moved along the horizontal rod H. Motion upon the plate is facilitated by a small roller R on the lower end of rod V. Five horizontal lines drawn on the chart are used as base lines in recording five evenly spaced contour curves for each plate. One inch from the rear edge of plate S, the roller R follows a path which corresponds to the curve over the base line uppermost upon the chart. The plate is then moved by sliding base B to a point $3^1/_2$ inches to the rear, where a second cross-section is drawn as a curve on the chart, over the next lower base line. The three remaining cross-sections are recorded in a similar manner. For easy comparison the subsequent warpage measurements for the same plate are made upon the same chart.

Figure 3 shows diagrammatically the appearance of a sample chart. The curves corresponding to the ground and cover coats are marked G and C, respectively. The base lines are denoted by B. The amount of warpage is an average of the areas between the five base lines and the cor-

responding contour curves. These areas were determined with an integraph and are expressed in square centimeters. This method takes into account warpage in any direction. Thus, the sample chart shown in Fig. 3 represents a bending up of the plate at the right and left sides, and also the edge next to the observer, since base lines Nos. 4 and 5 are not touched by their corresponding curves. The areas over these base lines are larger as a consequence of warpage in the second direction, and the average area is correspondingly increased.

For measurement each test plate was placed concave side up in order that warpage measurements might be comparable throughout the work.

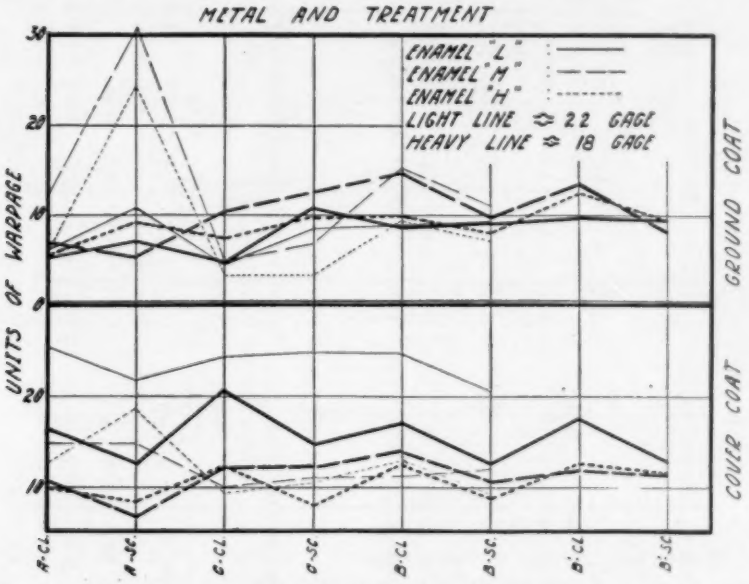

FIG. 4.—Effect upon warpage of method of cleaning metal (Sc. = scaled and Cl. = cleaned).

Results

1. Effect of Variation in Method of Cleaning Metal

The relation between the warpage of cleaned and scaled plates is given in Table III and is shown graphically in Fig. 4. It is appropriate here to explain that in Table III and the corresponding Fig. 4, the high warpage values for the ground-coated A metal of 22 gage, which had been scaled, are believed to be due to the sudden cooling of the plates as they were removed from the furnace, caused by draughts from open windows. This view is based on the contrast between these values and the decidedly smaller ones for those plates which were handled under conditions which were identical except that

TABLE III

AVERAGE WARPAGE MEASUREMENTS FOR CLEANED AND SCALED PLATES. EACH VALUE IS THE AVERAGE FOR 6 PLATES

Units of Warpage

	18 Gage								22 Gage					
	A		C		B		B′		A		C		B	
Enamel	Cl.	Sc.	Cl.	Sc.	Cl.	Sc.	Cl.	Sc.	Cl.	Sc.	Cl.	Sc.	Cl.	Sc.
Ground L	5.3	7.2	4.9	10.8	8.6	9.0	9.8	9.5	6.7	10.9[1]	4.7	8.6	8.9	9.4
Ground M	7.0	5.5	10.4	12.6	14.8	9.8	13.6	8.1	12.0	30.8[1]	5.2	6.9	15.3	11.1
Ground H	5.5	9.3	7.6	9.9	10.0	8.2	12.5	9.4	6.1	24.4[1]	3.5	3.6	9.5	7.4
Cover L	16.4	12.4	20.7	14.8	17.1	12.5	17.6	12.7	25.5	21.8	24.5	24.9	24.8	20.7
Cover M	10.8	6.9	12.2	12.3	14.2	10.6	12.0	11.5	14.9	14.9	10.1	11.1	11.3	12.1
Cover H	9.8	8.5	12.4	8.1	12.5	8.8	12.7	11.6	12.7	18.7	9.5	10.7	13.2	9.4

[1] These values should not be used for comparison with the others in the table, as explained in the text.

TABLE IV

AVERAGE WARPAGE MEASUREMENTS SHOWING EFFECT OF VARIATION IN FIRING TEMPERATURE. EACH VALUE IS THE AVERAGE FOR 6 PLATES

Units of Warpage

		825°C				875°C					925°C				
Enamel	Gage	A	C	B	B′	Av.	A	C	B	B′	Av.	A	C	B	B′	Av.
Ground M	18	5.7	8.5	10.8	10.4	8.9	9.4	10.7	12.1	11.4	10.9	12.6	10.9	10.1	10.4	11.0
	22	3.8	4.8	11.4	....	6.7	7.2	7.0	14.4	....	9.5	17.7	21.5	11.1	....	16.8
				Total Av.		7.8			Total Av.		10.2			Total Av.		13.9
Cover M	18	9.8	11.2	10.4	9.8	10.3	8.6	12.5	9.8	12.8	10.9	8.2	10.9	10.4	12.3	10.5
	22	9.6	9.1	10.0	....	9.6	8.8	11.8	11.1	....	10.6	11.8	13.1	9.8	....	11.6
				Total Av.		9.9			Total Av.		10.7			Total Av.		11.0

the draughts of cold air were eliminated during the cooling. These high values should not be considered in comparing the effect of the other factors upon warpage. A study of Table III and Fig. 4 shows that the effect of method of cleaning varied with the type of metal treated. Thus, for the steel (metals B and B′) we find that the scaled plates are warped distinctly less than the cleaned plates either 18 or 22 gage, and this is true both after the application of the ground coat and after the ware is finished. Considering the iron (metals A and C), we find, on the other hand, that the tendency is for the cleaned plates to be warped less after being ground-coated. After

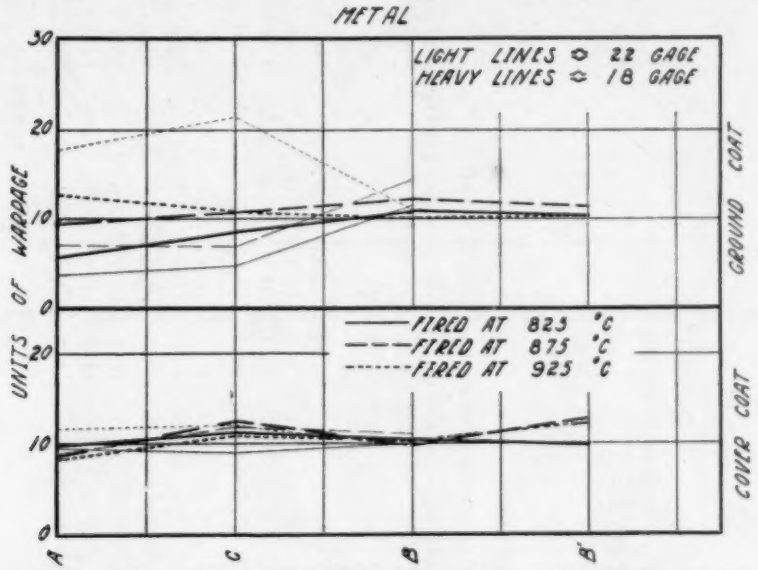

FIG. 5.—Effects of variations in firing temperature, and type and gage of metal, for both ground coats and cover enamels.

application of the cover coats the results for the 18-gage iron stock agree well with those for the steel, the scaled plates showing less warpage. The warpage values for 22-gage iron after receiving the cover coats, although not entirely consistent, are, with one notable exception, also in favor of the scaling treatment. Since the manufacturers are concerned chiefly with the condition of the finished ware, it may be said that the results of this investigation indicate that scaled metal shows less tendency to warp than cleaned metal.

2. Effect of Variation in Firing Temperature

Figure 5 shows graphically the relation between the warpage values of plates fired at 825°C, 875°C, and 925°C (1517°F, 1607°F, and 1697°F), respectively. A tabulation of the warpage values is found in Table IV, with the time for firing shown in Table IV-a.

TABLE IV-a

BURNING TIME FOR TABLE IV

Enamel	18 Gage 825°C	18 Gage 875°C	18 Gage 925°C	22 Gage 825°C	22 Gage 875°C	22 Gage 925°C
Ground M	4′–45″	3′–5″	1′–50″	4′–15″	2′–35″	1′–25″
Cover M	1′–35″	1′–20″	1′– 5″	1′–10″	–55″	–45″

TABLE V—CORRESPONDING TO FIGS. 6 AND 6-a

AVERAGE WARPAGE MEASUREMENTS FOR PLATES RECEIVING VARIATION IN SCALING TREATMENT. EACH VALUE IS THE AVERAGE FOR 3 PLATES

Units of Warpage

	18 Gage A P	18 Gage A G	18 Gage C P	18 Gage C G	18 Gage B P	18 Gage B G	18 Gage B′ P	18 Gage B′ G	22 Gage A P	22 Gage A G	22 Gage C P	22 Gage C G	22 Gage B P	22 Gage B G
Scaled at 850°C	18.6	4.0	19.2	9.0	17.7	8.8	16.4	7.6	32.6	16.5	34.7	10.1	33.6	7.6
Scaled at 900°C	29.5	12.7	15.8	11.7	27.1	11.5	20.1	8.2	46.6	11.8	40.5	11.7	38.3	6.4
Scaled at 950°C	21.0	10.6	27.9	15.6	25.1	10.3	30.4	4.8	32.1	12.0	26.2	11.5	28.4	7.7
Coated with Ground L	10.9	8.4	6.0	8.7	9.0	11.1	7.4	8.4	9.0	9.1	8.4	10.0	14.1	14.6
Coated with Ground M	12.6	9.2	9.5	11.5	10.8	10.1	11.3	10.2	12.1	12.5	12.2	8.5	14.0	10.3
Coated with Ground H	17.0	7.2	20.2	11.1	9.6	12.1	9.5	12.0	8.4	10.0	11.5	8.6	11.8	10.4
Coated with Cover L	19.8	18.1	19.1	17.3	16.5	16.6	13.8	13.0	23.4	23.9	27.3	19.4	19.3	22.3
Coated with Cover M	14.8	11.6	13.5	14.1	11.7	11.2	14.9	14.5	13.8	12.2	16.6	10.8	12.4	12.7
Coated with Cover H	21.1	12.2	23.4	16.3	15.2	14.8	13.2	16.7	15.2	16.9	16.0	16.7	14.5	13.5

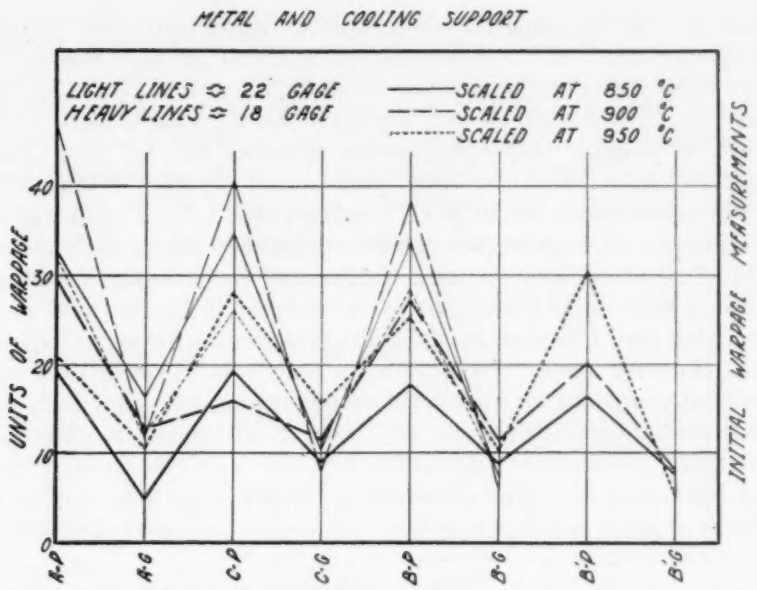

FIG. 6.—Effect of scaling temperatures and type of cooling support on warpage before enameling.

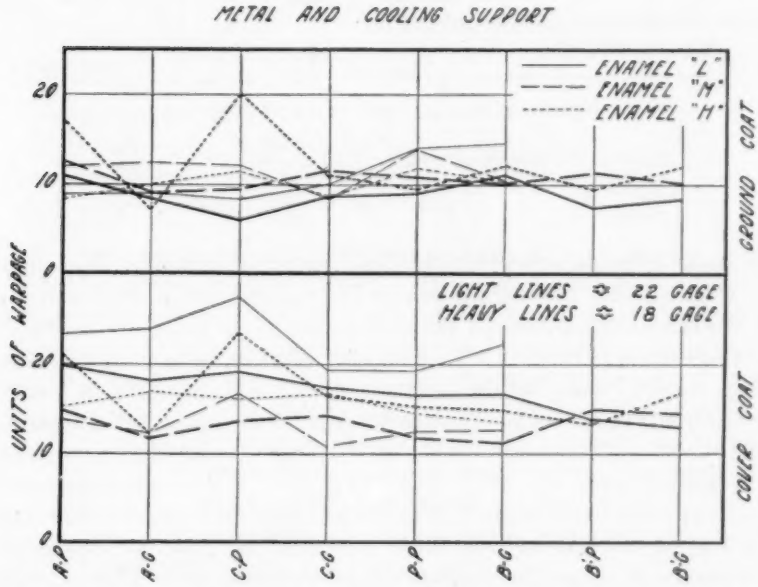

FIG. 6-a.—Effect of variation in support during scaling on warpage during enameling.

Here also, in discussing the effect of firing temperature upon warpage, a distinction must be made between the iron and the steel used in this work. This difference is most noticeable in the ground-coated 22-gage plates, which, in the case of iron (metals A and C), show a very marked increase of warpage as the temperature increases, but for steel (metals B and B′) show about the same warpages at the three temperatures. The 18-gage plates, as might be expected, are affected to a smaller extent, but otherwise the same relation as obtained for the lighter gage holds true.

The effect of variation in firing temperature is consistent and decisive for the ground-coated plates, but has a tendency to become more or less obscured in the subsequent handling and firing accompanying the application of two cover coats. Thus, while the cover coat values do show up in agreement with those for the ground coats in many cases, they seem to be sufficiently obscured to prevent any positive interpretation. The small effect shown for the cover coat may be partially due to the relatively short firing time, and to other factors which become operative, such as the relieving of strain which undoubtedly takes place in a warped plate upon subsequent firing.

3. Effect of Variation in Scaling Treatment

a. The relative effect of the four pins arranged in an 8″ square, and the iron grid, as cooling supports, is shown graphically in Figs. 6 and 6-a, and in tabular form in Tables V and V-a. Table V-a is obtained by condensing Table V.

TABLE V-a

EFFECT OF SCALING TREATMENT ON WARPAGE

	Units of Warpage		
Cooled on	Initial measurement	Ground-coated	Cover-coated
4 pins	28.9	11.3	17.0
Grid	9.8	10.2	15.6

It should be understood that the pins, representing poor cooling support, were used only for the scaling treatment, and that the ground- and cover-coated plates were cooled on the grid in the usual manner. In Fig. 6-a, therefore, the letters P and G (pins and grid) refer only to the type of cooling support used for the scaling process, and similarly in Tables V and V-a the types of support indicated apply only to the initial treatment. In this way the effect of initial warpage of the metal could be traced through to the finished ware.

It is apparent from Table V that the plates cooled on pins after scaling were warped much more than those cooled on the grid, but this is not at all pronounced after the application of the enamels. This is another example of the tendency for the effect of one factor upon warpage to be modified in the successive processes of enameling the ware.

b. The effect of time of scaling is also graphically illustrated in Fig. 7. Table VI, compiled from the averages of values shown in Fig. 7, shows the relative effect of 2-, 4-, and 6-minute scaling periods upon the plates before enameling and after firing the ground coat and the cover enamels.

From this table it can be seen that the warpage for the longer scaling period is greater at the initial measurement. This is quite true of the plates cooled on the regular grid, which furnished normal and adequate

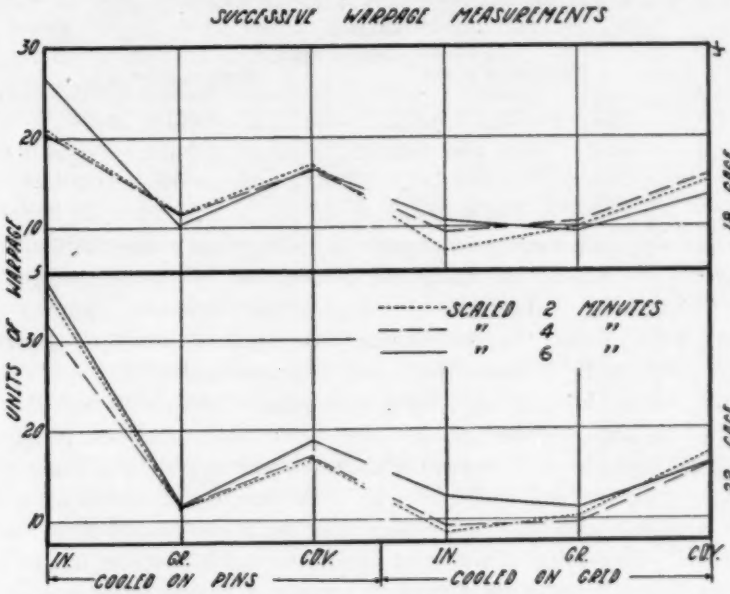

FIG. 7.—Effect of time of scaling and cooling support on warpage before enameling, after ground coating and after cover coating. (IN. = initial, GR. = ground coat, and COV. = cover coat.)

support. Here again the effect diminishes with further handling so that the values for ground- and cover-coated sheets show only small, somewhat inconsistent differences. This is true for 18- and 22-gage stock, although the 22-gage metal cooled on the 4 pins, as might be expected, showed more warpage at the initial measurement than the corresponding 18-gage.

4. Effect of Variations in Expansivity of the Enamels

In a discussion of the effect of the expansivity of enamels upon warpage it should be borne in mind that the metal plates without enamel, when subjected to the heat treatment that they would receive if an enamel were being applied, tended to warp upward at the edges.

A cover enamel applied to the top side only, having an expansivity greater than that of the metal base, would be expected to increase the

tendency of the test piece to warp upward, while one having a coefficient of expansion less than that of the metal base should produce the opposite effect. When the application is on both sides of the sheet, as in the case of the ground coats in this investigation, there is some effect upon warpage, but obviously this is not as great as when the application is on one side only.

TABLE VI

AVERAGE WARPAGE MEASUREMENTS SHOWING EFFECT OF VARIATION IN TIME OF SCALING

Units of Warpage

Time of scaling in minutes	Plates cooled on pins			Plates cooled on grid		
	Initial measurement	Ground-coat measurement	Cover-coat measurement	Initial measurement	Ground-coat measurement	Cover-coat measurement
2	28.3	11.4	16.7	7.9	10.1	16.1
4	26.2	11.8	16.5	9.3	10.1	15.7
6	31.6	10.8	17.7	11.8	10.3	15.7

A basis for comparing the warpage values of plates coated with enamels of varying coefficients of expansion is afforded in the following data: Table III and Fig. 4 dealing with comparative methods of cleaning (Sec. A), and Table V and Fig. 6-a dealing with variation in scaling treatment (Sec. C). A study of these tables and diagrams indicates that enamel L produces, on the average, somewhat less warpage for ground-coated plates than the M and H enamels. For the cover coat, however, which was applied to only one side, enamel L entirely overcame the tendency of the plates to warp upward, and produced in the opposite direction a warpage which decidedly exceeded that observed in the plates coated with enamels M and H. In section C the warpage of the finished plates coated with enamels H was greater than that of the plates coated with enamels M, although in section A this was not the case.

The direction of warpage, in accordance with the above theoretical discussion, was strongly influenced by the expansivity of the enamel, being away from the enamel on every plate coated with enamel L, toward the enamel on most of the plates coated with enamel H, and irregular on the plates coated with enamel M.

It is interesting to note here that ground coat L displayed a marked tendency to fish scale, while enamels of high expansivity tended to craze although the results which corroborate this statement are not tabulated in this report.

5. Effect of Variation in Source of Sheet Metal

Figures 4, 5 and 6-a constitute a graphical means for comparing the warpage undergone by the metals obtained from the different manufacturers. A condensation of the values indicated in these figures is given in Table VII, which shows the warpage values obtained in each of the three sections of the investigation.

From this table it is apparent that there is no marked difference in the warpage of the finished ware which can be attributed to the source of metal, when all factors affecting warpage are allowed to operate. Certain specific factors, however, seem to affect the iron and steel used in this investigation differently. It will be recalled that method of cleaning affected the steel and iron in somewhat different ways. Also from Fig. 5 it may be noted that metal B (steel), especially for the ground coat, seems less affected by variations in firing temperature than metals A and C (iron). Thus at 825°C (1517°F) the iron is warped less than the steel, while at 925°C (1697°F) the steel has not changed, but the warpage of the iron has increased sufficiently to exceed that of the steel. It should be pointed out that this difference in behavior might be due to factors other than differences in chemical composition of the iron and steels, because different metallurgical processes produce different physical properties in metals of the same composition. It is quite possible, therefore, that specimens of sheet iron and steel manufactured under different conditions might give different results.

6. Effect of Variation in Gage of Metal

Figures 4, 5, 6 and 6-a also take into account the difference between the 18- and 22-gage metal. It is at once apparent from any of these diagrams, or the corresponding tables, that most of the highest warpage values and some of the lowest correspond to 22-gage metal. This fact is interpreted to mean that 22-gage metal is more sensitive to the factors affecting warpage than 18-gage. That is, if a given factor were allowed to operate upon two plates having an equal warpage, one of each gage, whose only difference was one of thickness, the 22-gage plate would be affected to a greater extent than the 18-gage plate, whether the factor in operation tended to increase warpage or to decrease it. This point is brought out especially well in that part of Fig. 5 which deals with the

TABLE VII

AVERAGE MEASUREMENTS SHOWING EFFECT OF VARIATION IN METAL UPON WARPAGE. EACH VALUE IS THE AVERAGE FOR 36 PLATES

Enamel	Gage	Units of Warpage											
		Average values from Table III (Sec. A)				Average values from Table IV (Sec. B)				Average values from Table V (Sec. C)			
		A	C	B	B'	A	C	B	B'	A	C	B	B'
Ground	18	5.9	9.4	10.1	10.5	9.2	10.0	11.0	10.7	10.9	11.2	10.5	9.8
	22	8.3	5.5	10.3	....	9.6	11.1	12.3	....	10.2	9.9	12.5	....
Cover	18	10.8	13.4	12.6	13.0	8.9	11.5	10.2	11.6	16.3	17.3	14.3	14.4
	22	18.1	15.2	15.3	....	10.1	11.3	10.3	....	17.6	17.8	15.8	....

ground-coated plates. Here metals B and B′ show but slight effect in either gage from the factor being varied, and therefore their warpage values do not concern the point under discussion. The warpage of metals A and C, however, is plainly affected by variations in firing temperature, and in the case of both metals the 22-gage plates give both the upper and lower extremes of warpage values. A study of Tables III, IV and V shows that on the whole the warpage of the 18-gage finished ware was less than that of the 22-gage.

Accurate measurements of the gage of each individual plate did not show sufficient variation to appreciably affect results.

7. Effect of Two Extra Cover Coats The warpage values obtained after the application of the second and fourth cover coats did not produce noteworthy changes in warpage, and the results obtained are therefore omitted in this report.

Conclusions

The results of this investigation show that a number of factors have a bearing on the warpage of sheet iron and steel in the enameling process. It is believed that the results are as consistent as might be expected in an investigation conducted on the scale of this study and which has to deal with a large number of factors, all of which appreciably influence results. The data obtained would seem to justify the following conclusions, bearing in mind that while the various factors dealt with appear to be important, some of their effects may be partially or entirely obscured in the finished ware, due to the fact that some of them become fully operative only in the later steps of the enameling process and may tend to nullify the effects produced in preceding stages of manufacture.

1. The application of a cover enamel having a coefficient of expansion widely divergent from that of the metal base decidedly increased warpage in the finished ware, upon which the enamel was applied to only one side.
2. Finished plates from which the grease had been burned preparatory to enameling (scaled) showed less warpage on the whole than those from which the grease had been removed chemically (cleaned).
3. The lighter gage metal, as might be expected, was more sensitive to the factors affecting warpage.
4. The iron base used in this investigation appeared to be less liable to warpage from ground coating at the lower temperatures employed for enamels, while the steel apparently developed less warpage at the higher temperatures. It is pointed out that this might be a special case for these particular lots of metal.
5. Sudden and irregular cooling of the ware after firing induced warpage.

6. The tendency to warp was reduced by properly supporting the ware during firing and cooling.

Summary

It is believed that this investigation, which is regarded as being of a preliminary nature, furnishes data which will be useful as a basis for further investigation. A study of the results suggests that metallurgical factors have a considerable influence on the warpage of sheet metal in the enameling process, and it is evident that a complete solution of the warpage problem must include a consideration of such factors. Specifically, it is suggested that any further investigation upon this subject could profitably include the effect upon warpage of a reduced and controlled rate of change of temperature and a uniform heat distribution for the scaling and firing processes. With these factors under control, opportunity would be afforded to correlate them with and adjust them to the properties of the enamel itself, with a possible beneficial effect upon warpage. A full solution of the problem of reducing warpage to a minimum, then, apparently necessitates working with conditions which could be obtained in the factories only through change in the present enameling practice.

BUREAU OF STANDARDS
WASHINGTON, D. C.

AN APPARATUS FOR MEASURING THE ABRASIVE HARDNESS OF GLAZES[1]

By W. J. Scott

ABSTRACT

An apparatus for measuring the resistance to abrasion, or scratching, of glazes and possibly other materials is described. It provides, essentially, for the wearing away of the surface by means of standard cement sand, which is allowed to run through a funnel adjusted to deliver a definite amount of sand for a given time interval, and to strike the inclined surface of the test piece after falling a fixed distance. The loss in weight under this treatment is assumed to bear a definite relation to the resistance to abrasion.

Introduction

The resistance of ceramic glazes to abrasion, or scratching, affects their usefulness for most purposes. A means of determining this quality is necessary in order to study the factors which may control it, such as temperature of firing, composition, thickness, etc., and in order to provide data upon which specifications may be based. The ideal test is the actual use of the ware under service conditions, but the time involved, the difficulty in ascertaining what the service really is, and in interpreting the results, make it impracticable for most purposes. A test, to be of practical value to the plant manager as well as to the laboratory investigator, must be rapid, easy to perform, and require apparatus of simple and rugged construction, but which, nevertheless, is capable of measuring small variations in this quality of the glaze.

A number of methods requiring various types of apparatus have been proposed; for example, penetration by a needle under pressure, scratching of needles, the use of abrasive wheels, the sand blast, and rotation in a cylinder with an abrasive sand. Tests using these methods are difficult to standardize. The effect obtained by the scratching of needles depends on the sharpness of the point used, on the pressure, and the manner in which the point is applied to the test piece. Control of such conditions is impossible in a practical way. The sand blast gives a variable pressure and volume of sand, both of which are difficult to control even with specially designed apparatus. The measurement of the depth of penetration with any accuracy, by means of microscope or micrometer, is difficult. An exhaustive study of such methods was not, however, made in this investigation because of the greater promise of the following method developed at this Bureau. It was found that the use of a stream of falling sand gave very consistent results on material of the same kind, and, when several brands were tested, the loss in weight seemed to be a satisfactory index of the relative resistance to abrasion.

[1] Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce. Received Jan. 28, 1924.

Apparatus Used

The complete apparatus now in use is shown in Fig. 1. The opening in the bottom of the sand hopper is set so as to keep the small adjustable funnel beneath it just full of sand. The funnel, shown in detail in Fig. 2, has for its sides two steel plates $5^5/_8$ inches long, set at an angle of 60° to each other, and capable of sliding in grooves in the thicker aluminum ends, which are $3^3/_4$ inches apart.

The width of the lower opening can be adjusted to give a definite flow of sand by means of the graduated adjusting screws. From the lower opening of the funnel the sand drops $4^1/_2$ feet to the surface of the test piece which rests on an adjustable support, capable of vertical adjustment, of being leveled, and of being inclined (at the desired angle of approximately 24°) from front to back.

The specimen is prevented from slipping off the support by thumb tacks pressed into its wooden top, or by any other suitable device.

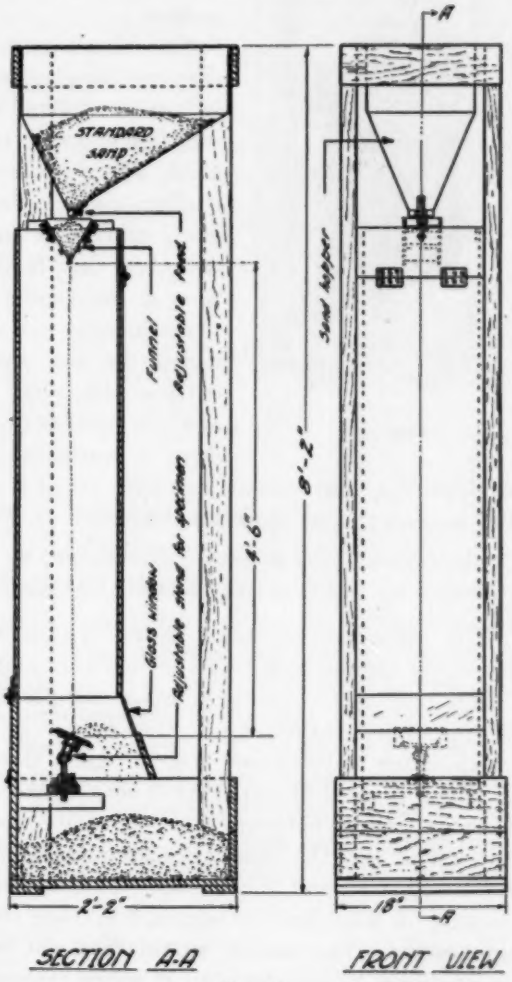

FIG. 1.

The abrasive used is standard Ottawa sand, prepared for cement testing by screening to pass a 20-mesh and remain on a 30-mesh screen, and is allowed to fall on each piece at the rate of 64 pounds in ten minutes, the test period used in this work. The test piece must contain a relatively flat area at least $1^1/_2$ by $4^1/_2$ inches.

The details of construction and operation described above are the re-

sult of numerous tests on the effect of type of funnel, height of fall, time of test, and so forth. The standard sand was selected on account of its uniformity. The height of fall is limited by head room for the apparatus, and the spreading of the sand stream as the height increases. Variations in the pressure head of sand are eliminated by the separate hopper.

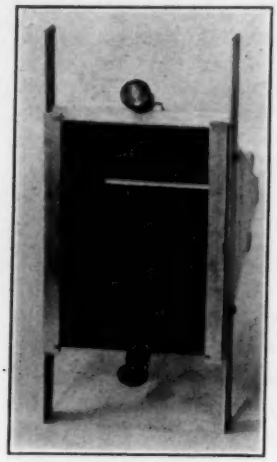

FIG. 2*a*.

The funnel as described has the advantage over circular glass funnels which were first used, in reproducibility, and in that the sand grains interfere less with each other in striking the test piece, which produces a greater loss in weight in a given time. The opening of the funnel is made adjustable to permit control of the sand delivered, and to compensate for any possible wear at the opening.

Preliminary tests indicate that the angle at which the test piece is inclined gave greatest cutting action for the same weight of sand, and the test period used is sufficient to produce a satisfactory loss in weight. Further modifications may become necessary when a more comprehensive study of the method and its application is made.

Results Obtained

The accompanying table shows typical data obtained on several brands of the common types of tableware and also on plate glass. Trials 1 and 2 in each case were made on pieces broken from the same plate. The loss in weight given is for a 10-minute test on each trial. A larger number of tests may show a different average range between types, brands and specimens, but the brands are thought to be representative, and the results, therefore, indicative of what may be obtained in using the apparatus. The loss in weight may not be proportional to abrasion, but it seems reasonable that a glaze giving a small loss in weight is more resistant to abrasion than one giving a greater loss. Plate glass, because it has greater uniformity than glazes, was found to be useful in checking the performance of the apparatus.

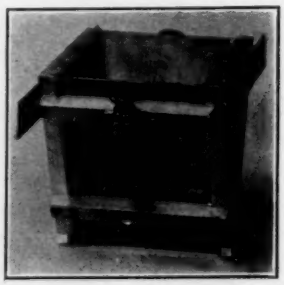

FIG. 2*b*.

TABLE I

Type of specimen	Loss in milligrams Trial 1	Trial 2
Plate glass 1	95	95
Plate glass 2	86	86
Semi-vitreous 1		
Specimen A	93	93
Specimen B	93	92
Specimen C	89	90
Semi-vitreous 2		
Specimen A	65	62
Specimen B	67	66
Semi-vitreous 3	71	72
Semi-vitreous 4	60	60
Vitreous 1	89	89
Vitreous 2		
Specimen A	70	76
Specimen B	68	..
Vitreous 3		
Specimen A	58	59
Specimen B	59	56
High-fire vitreous 1	46	45
High-fire vitreous 2	47	46
High-fire vitreous 3	43	42

Factors Affecting Accuracy

Some factors which must be considered because of their possible effect on the accuracy of the determinations are the wearing of the sand grains, the accuracy of the weighing, the humidity, and the slight curvature of the surface of the test-piece. Occasional checking against a standard material is expected to eliminate the first source of error, although it is believed to be slight for a limited number of runs because a screen analysis of some sand used about 75 times showed that it still passed the test for standard sand, and that the per cent through 30-mesh had increased from 0.36% to 0.86%. The table indicates the value of the method for research work, and also for factory control and other purposes requiring less accuracy. It has not been noticed that either humidity, or curvature of the specimen, introduces errors, but it is intended to check these and other possible sources of error by tests.

Possibilities of the Apparatus

The following observations as to the advantages and possibilities of the apparatus seem justified:

1. The close agreement in results, obtained with test pieces of the same specimen, indicates satisfactory accuracy. This qualification, combined

with simplicity of construction, ruggedness, and ease of operation, make its use possible in plant as well as in research laboratories.

2. It apparently measures small differences existing in glazes of the same brand, and indicates wide variation in glazes of different brands and types.

The author wishes to acknowledge the assistance of R. R. Danielson and other members of the Ceramic Division in the development of the apparatus.

BUREAU OF STANDARDS
WASHINGTON, D. C.

UTILIZATION OF GEORGIA KAOLINS IN THE MANUFACTURE OF FACE BRICK[1]

By R. T. Stull[2] and G. A. Bole[3]

ABSTRACT

The availability of the sedimentary kaolins of Georgia for the manufacture of face brick, when blended with sufficient flux-bearing rock (aplite) and sand, has been demonstrated. Two representative clays were used. Four samples of aplite were mixed with varying amounts of the kaolins and fired to cones 6 and 12. The physical properties of the fired specimens are tabulated. Using this information as a basis, semi-commercial tests were run using varying percentages of kaolin, aplite and sand. Bricks were made up by both the dry press and stiff mud process and fired to temperatures around cone 9. Trouble was experienced due to excessive shrinkage and due to cracking with mixtures containing no sand. Due to lower drying shrinkage, the dry press method of manufacture was found to be better suited to certain mixes than the stiff mud process. A mix was finally produced which went through the stiff mud process nicely, dried safely, and burned to a dense, light buff body at cone 8½. The total shrinkage of this body was comparatively low.

Introduction

Throughout the southeast, and more especially in the Coastal Plain States, no clays have been found from which face brick, light cream to clear buff and light gray in color, can be made. Large quantities of such brick are used in this territory for building purposes and substantially all are shipped in from north of the Ohio and Potomac Rivers.

These desirable light colored brick carry a freight charge of $18.00 to $20.00 per thousand, bringing their delivery cost up to about $48.00 to $55.00 per thousand.

Clays in Georgia suitable for the manufacture of face brick of red through brown to gun metal hues are comparatively scarce. These are confined mostly to the variable clays derived from the decomposed granites, to alluvial clays more or less sandy and irregular, and to shales in a small area in the northwestern corner of the state.

The bulk of the cream, buff and gray brick finding their way into the southern market are made from No. 2 fire clays, generally obtained by underground mining. The coal measure clays of the south, and more especially those of Georgia and Alabama, are high in iron and burn to a dark color not at all comparable to the light colored brick made from the fire clays of the Freeport, Mercer and Kittanning formations of Ohio and Pennsylvania. For several years brick manufacturers have been searching the south for clays from which buff and lighter shades of brick could be made. Up to the present time their efforts have not been rewarded.

The geology of the country indicates that no clays are likely to be found

[1] Published by permission of the Director, U. S. Bureau of Mines. Presented at the Atlantic City Meeting, Feb., 1924. (Heavy Clay Products Division.)

[2] Assistant General Industrial Agent, Central of Georgia Railway Company.

[3] Superintendent, Ceramic Experiment Station, U. S. Bureau of Mines.

which in themselves will produce brick equal to those made from the No. 2 fire clays of Ohio and Pennsylvania. It, therefore, occurred to the senior writer that the best possibility of producing such brick would be to utilize the sedimentary kaolins of the Coastal Plain in a synthetic mixture by adding the necessary fluxes lacking in them.

A previous investigation of the sedimentary kaolins of Georgia has shown their high refractory value.[1] Their refractoriness is due mainly to their low content of fluxing impurities. It would, therefore, be impractical to make face brick from these kaolins alone, because the temperature required to burn them dense to vitrified would be too high to attain economically. Even when burned to a vitrified condition, the shrinkage is so great that warping and cracking are excessive.

In the Piedmont Plateau to the north, and bordering the kaolins of the Coastal Plain comparatively large deposits of aplite are found. These deposits occur in dikes and vary from a few feet to over a thousand feet in width. These aplites are composed mostly of mixed feldspars and quartz with very little or no mica. The microscopic examination of several specimens indicates that they are composed principally of orthoclase, albite, microcline and quartz. Their iron content as Fe_2O_3 varies from 0.5% to about 2.0%, and their combined alkali and alkaline-earth content from 6% to 14%.

Chemical analyses of specimens of these rocks from different localities show considerable variation in composition. The rocks are neither pure nor white enough to be useful for high-grade ceramic purposes and in fact no important commercial use has been found for them except the local use of the partly weathered outcrops as road material.

These aplites contain the desirable fluxes lacking in the kaolins, and by mixing them in proper proportions to produce the desired fluxing action and adding sufficient quartz sand (usually found below the clays), to control the shrinkage, good face brick can be made, varying in color from a light cream, light buff to light gray, the color depending upon the iron content in the raw materials and the burning treatment.

The coöperative agreement between the Bureau of Mines and the Central of Georgia Railway Company originally included the investigation of the kaolins, bauxitic clays and bauxites for pottery, fire brick and filler purposes. The possibility of producing a light-colored face brick by utilizing the kaolins, made it possible to extend the coöperative agreement to include this investigation.

Small Scale Tests

The first tests were made with small trial pieces and these were followed

[1] R. T. Stull and G. A. Bole, "Refractory Possibilities of Some Georgia Kaolins," *Jour. Amer. Ceram. Soc.*, **6** [5], 663 (1923).

by the large scale tests in which full sized brick were made under practical conditions.

Aplite Used

Preliminary experiments were made to determine the fluxing effects of different aplite samples on Georgia kaolin.

Four different samples of aplite designated as M-1, M-2, M-3 and M-4 were taken from different exposures. Sample M-1 was taken from an exposure where the weathered portion has been removed for road dressing. It was hard, unweathered and dull pink in color. It softened at cone 12 to a light gray porcelain-like glass. The chemical analysis and empirical formula are as follows:

Moisture (at 105°C)	0.02	P_2O_5	0.02
Ignition loss	0.44	CaO	0.54
SiO_2	84.00	MgO	0.11
Al_2O_3	8.93	K_2O	3.13
Fe_2O_3	0.50	Na_2O	2.66
TiO_2	0.02		
		Total	100.37

FORMULA

$$\left.\begin{matrix}0.376\ K_2O\\0.484\ Na_2O\\0.109\ CaO\\0.031\ MgO\end{matrix}\right\}\quad\left.\begin{matrix}0.988\ Al_2O_3\\0.035\ Fe_2O_3\end{matrix}\right\}\quad 15.6\ SiO_2$$

The constitution of the aplite as calculated from the formula indicates that it is composed of the equivalent of approximately: 18.82% orthoclase, 22.83% albite, 6.49% anorthite,[1] 51.86% quartz. No chemical analyses were made of samples M-2, M-3 and M-4. They were partly weathered and somewhat iron-stained in the seams. Their deformation temperatures were cone 12 for M-2 and M-3 and cone 9 plus, for M-4. The color of M-2 and M-3 when fused was light brown while M-4 was apparently more iron stained and fused to a darker color.

Clays Used

For the preliminary tests, kaolins G-3, G-8 and G-15 were selected and for the large scale tests, kaolins G-8 and G-35. The chemical analyses and deformation temperature of these kaolins are as follows:

	G-3	G-8	G-15	G-35		G-3	G-8	G-15	G-35
Moisture (105°C)	1.15	1.33	0.74	...	P_2O_5	0.05	0.04	0.04	..
Ignition loss	13.33	12.40	13.79	13.85	CaO	0.39	0.25	0.24	..
SiO_2	46.56	47.67	43.25	44.26	MgO	0.25	0.37	0.11	..
Al_2O_3	35.51	35.52	39.45	40.11	K_2O	0.00	0.16	0.16	0.43
Fe_2O_3	1.59	1.26	0.96	0.71	Na_2O	0.00	0.04	0.38	
TiO_2	1.29	1.28	1.17	0.90	S	0.03	0.08	0.15	..
					Cone	34	34	34+	34+

[1] For convenience the alkaline earths are calculated as "anorthite" although it is not probable that they occur in that form. The Fe_2O_3, TiO_2 and P_2O_5 are evidently impurities.

All four clays are very plastic and substantially of the same refractory value. G-3 is locally known as a "hard" kaolin as distinguished from a "soft" kaolin. The hard kaolins, when dry, require considerable force to crush by squeezing in the hand, whereas, the soft kaolins are very friable and crumble under a slight pressure. The hard kaolins do not slake readily and require grinding to place them in slip form. They are so fine grained and plastic they clog the filter sacks and make filter pressing next to impossible.

The bonding strength of G-3 is very good. Its iron and titania contents are comparatively high causing it to burn too dark in color for whiteware. It is, however, an excellent material for high grade clay refractories.[1]

Under the above classification, G-8 is known as a "semi-hard" kaolin. It contains occasional fine quartz grains and mica flakes. It slakes and filter presses slowly. It is very plastic and shows good bonding strength. Its color, when burned, is too dark for whiteware, though it is lighter in color than G-3.

G-15 is locally called a "blue clay." It would be classed between the semi-hard and the soft kaolins. It represents the lower 15 to 20 feet of a working mine of 35 to 50 feet in thickness. Its blue color (evidently due to organic stain), is such that it is not a desirable clay for filler purposes. However, it burns sufficiently white to be of value for whiteware.[2] It slakes readily and filter presses slowly. It is very fine grained, highly plastic and has fair bonding strength.

G-35 is decidedly a soft kaolin. It is very white and friable. Although very plastic, it has comparatively low bonding strength. Its alumina content is comparatively high and its iron and titania contents comparatively low. It slakes and filter presses readily and is a suitable paper filler as indicated by tests.[3] It burns to a good white and is mined and shipped crude, principally to the floor and wall tile trade.

Preliminary Tests

For the preliminary tests, G-15 was used in combination with the four different aplites (ground to 65-mesh) and potters flint in mixtures according to the following table.

The mixtures were kneaded into a good plastic condition and the trial pieces molded by hand in the form of two-inch cubes. These were dried and fired to cone 6.

There was comparatively little difference in the appearance of the trials

[1] Stull and Bole, *loc. cit.*

[2] G. A. Bole and R. T. Stull, "Use of Sedimentary Kaolins of Georgia in Whiteware," *Jour. Amer. Ceram. Soc.*, **6** [7], 854 (1923).

[3] W. M. Weigel, "Georgia Clays for Paper Fillers," *Paper Trade Journal*, August 9, 1923.

made from the same aplite. Trials containing M-1 were a cream color while those containing M-2, M-3 and M-4 were light buff. All contained a few fine black specks which improved their appearance. The structure of the trials appeared to be good even though their porosities were com-

GROUP I

No.	G-15	Aplite	Flint
1	55	45	0
2	50	50	0
3	45	55	0
4	50	40	10
5	50	35	15
6	50	30	20

paratively high. Trials containing 50 to 55 aplite and 50 to 45 kaolin showed lowest porosity, the average being 19.3%. At cone 6 there appeared to be no marked difference in the porosity of trials containing M-4 as compared to the others even though its deformation temperature was three cones lower.

Results of Cone 12 Burn

To produce a vitrified condition and to observe its influence upon the color and general appearance, a duplicate set of Group I was burned to cone 12. Trial pieces were also placed in the kiln to observe the behavior of kaolins G-3 and G-8 in combination with the four different aplites. These mixtures were composed to 50% kaolin and 50% aplite and designated as Group II.

At cone 12, the colors varied from a gray-white in trials containing M-1 aplite and G-15 kaolin to a medium gray in trials containing M-4 aplite and G-3 kaolin. The fine black specks were developed more prominently and gave the trials the appearance not unlike light colored, fine grained granite. To the eye, the structure of the trials appeared dense and well vitrified although the average porosities of the different mixtures varied

COMPARISON OF AVERAGE POROSITIES OF TRIAL PIECES CONTAINING DIFFERENT APLITES

Aplite sample	Av. porosity, per cent Group I	Av. porosity, per cent Group II	Av. porosity, per cent Groups I & II
M-3	4.61	5.12	4.74
M-1	5.69	5.14	5.55
M-2	7.52	9.37	7.98
M-4	11.35	14.20	12.06

from about 4% to 14%. The porosity is evidently due in part, at least, to the coarser grinding and coarser structure as compared to true porcelain.

The fluxing values, of the four different aplites as indicated by the porosity determinations, were indicated rather prominently as shown in the following table. Compositions containing M-3 showed lowest porosi-

ties, while those containing M-4 were highest. No satisfactory explanation for the lower fluxing value of M-4 is apparent in view of its lower deformation temperature.

Full Sized Brick Trials

For making standard size brick, clays G-3 and G-8 were selected principally because neither was considered good enough for whiteware and because they represented undeveloped properties. Inasmuch as there was not enough of any one sample of aplite left for the full sized brick tests, the remainder of the four aplites from the foregoing tests were mixed and ground to pass 65 mesh. The quantity of M-4 was much in excess of the others. In fact it comprised about $^3/_4$ of the mixture.

Mixtures of each kaolin (G-3 and G-8) and aplite were made consisting of 50 kaolin and 50 aplite. Part of the mixtures were molded "dry press" on a small hydraulic machine. The remainder of the mixtures were tempered to a plastic condition, molded by hand and repressed. The brick were dried and burned to cone 10 and shrinkage and porosity determinations made.

TOTAL LINEAR SHRINKAGE AND POROSITIES OF BRICK MADE FROM KAOLINS G-3 AND G-8 WITH APLITE. BURNING TEMPERATURE CONE 10

	Shrinkage, per cent	Porosity, per cent
G-3 (dry press)	5.00	22.50
G-3 (repress)	7.86	21.70
G-8 (dry press)	4.29	16.40
G-8 (repress)	8.57	16.45

No serious difficulties occurred in the drying or burning. The brick appeared to be of good color and sound structure. The color of the repressed brick was cream-gray while the dry press bricks were gray. Bricks containing kaolin G-8 were lighter in color than those containing G-3. All contained a few fine black specks.

Large Scale Tests

The small scale tests indicated the possibility of making face brick from kaolin and aplite rock, containing sufficient alkalies and alkaline earths to produce the desired fluxing action. The next step in the investigation was the determination of the working properties of such mixtures when molded in regular commercial size dry press and stiff mud machines and to determine their drying and burning behaviors. For the large scale tests, 8 tons of material were shipped to the Hadfield-Penfield Steel Company's testing department at Bucyrus, Ohio, where the tests were made,[1] under the writers' direct supervision.

[1] The writers are indebted to C. B. Shearer and Davis Brown of the above named Company for their interest and hearty coöperation in the work.

The Clay Used Two tons each of kaolins G-8 and G-35 were taken from the deposits in a manner to obtain fair average samples. Aside from the fact that both kaolins are very plastic, they differ considerably in other properties. As previously mentioned, G-8 belongs to the semi-hard class. It does not burn to a good white, is not used for pottery or filler purposes but has good bonding strength. G-35 is a soft kaolin, burns to a good white, is sold to both the pottery and filler trades but has low bonding strength.

The Aplite Used Four tons of aplite were quarried from the same dike from which sample M-3 was previously taken for the small scale tests. The dike extends in a northeast-southwest direction and is cut by the railroad at about right angles, showing an exposure approximately 12 feet deep and about 400 yards in width.

The four-ton sample was taken about three feet in from the face and six to seven feet down from the top. The sample was light pink to cream in color, and although quite hard, it was partly weathered with iron stains and thin films of clay showing in the seams.

Inasmuch as no fine grinding equipment of sufficient size was available, the sample was first shipped to a commercial grinding plant where it was ground to pass 60-mesh, then reshipped to Bucyrus for the tests.

Following are the analysis of an average sample of the ground aplite, the empirical formula and the calculated mineral constitution. Its deformation temperature was cone 10.

CHEMICAL ANALYSIS

H_2O (at 105°C)	0.40
Ignition loss	1.62
SiO_2	73.30
Al_2O_3	15.00
Fe_2O_3	1.51
TiO_2	0.17
P_2O_5	0.01
CaO	0.82
MgO	0.05
K_2O	4.13
Na_2O	3.37
Total	100.38

FORMULA

$$\left.\begin{matrix}0.3842\ K_2O\\ 0.4768\ Na_2O\\ 0.1281\ CaO\\ 0.0109\ MgO\end{matrix}\right\}\left\{\begin{matrix}1.2861\ Al_2O_3\\ 0.0825\ Fe_2O_3\end{matrix}\right\}\left\{\begin{matrix}10.684\ SiO_2\\ 0.787\ H_2O\end{matrix}\right.$$

APPROXIMATE MINERAL CONSTITUTION

	Per cent
Orthoclase	24.96
Albite	29.19
Anorthite[1]	8.39
Quartz	28.83
Kaolinite	8.63

[1] See foot-note reference p. 349, *This Jour.*

Mixtures Made

For the large scale tests, eleven different compositions were made consisting of 800 to 1000 pounds each. The materials were weighed on platform scales in batches of 200 pounds and tempered in a six-foot wet pan. After enough clay had been tempered with sufficient water for dry press molding, the remainder was tempered for molding by the stiff mud method. About 200 bricks were made from each mixture. Fifty to sixty of these were formed in a two-mold power driven dry press, and the remainder formed in a water-lubricated side-cut die attached to a stiff-mud auger machine. This brick machine has a rated capacity of 4000 to 7500 building brick per hour. The bricks were cut on a hand cutter set to cut fire brick size, or about $^5/_{16}$ inch wider than for cutting standard face brick.

After a mix had been expressed, the auger machine was cleaned before the next mix was introduced. The "left overs" from cleaning the machine were thoroughly mixed together and tested for molding properties in a "two hole" conduit die.

After the bricks were formed, they were dried in the open air to a leather-hard condition, then wrapped in paper, packed in excelsior and hauled by automobile to Columbus, Ohio, where the drying was completed and the brick burned at the Bureau's Experiment Station. The first lot of brick made in the large scale tests consisted of five different mixtures, as shown in the following table:

	Kaolin		
No.	G-35	G-8	Aplite
A-60	40	..	60
A-50	50	..	50
A-40	60	..	40
B-60	..	40	60
B-50	..	50	50

Results

All five compositions molded perfectly in both the dry press and stiff mud machines.

The stiff mud brick containing G-35 kaolin cracked some in drying. The cracking was considerably less in those containing 40% kaolin than those containing 60%. None of the brick containing G-8 kaolin cracked in drying.

The brick when bone dry were set in a round down draft gas fired kiln with a setting chamber of 39 inches diameter and 39 inches high. The brick were burned to cone 9 in $35^1/_2$ hours and the kiln cooled and brick removed 36 hours after the fires were shut off.

All brick containing kaolin G-35 showed small cracks which were evidently drying cracks not visible when the brick were set and which opened up in the burning. None of the brick containing G-8 cracked in the burning.

The brick appeared to be well vitrified and were light gray in color, those containing G-35 being considerably lighter. The shrinkage was very high as the brick came from the kiln with a decided "hollow face" or "dish."

In the following table are given the shrinkages of brick made from those mixtures which came from the kiln in a sound condition. These shrinkages as well as all others following are calculated on "die length" as basis:

LINEAR SHRINKAGES

	Drying, per cent	Burning, per cent	Total, per cent
B-60 (dry press)	0.00	8.70	8.70
B-60 (stiff mud)	2.94	8.33	11.27
B-50 (dry press)	0.00	7.73	7.73
B-50 (stiff mud)	2.94	7.84	10.78

The Addition of Salt

A second lot of brick were made of both kaolins with aplite and NaCl added to determine its influence upon shrinkage and overcoming cracking. The amount of NaCl which was added dry to the charge in the wet pan was a little less than two-tenths of one per cent. The compositions of these two mixtures were as follows:

KAOLIN

No.	G-35	G-8	Aplite	NaCl
A-55	45 lbs.	....	55 lbs.	3 oz.
B-55	....	45 lbs.	55 lbs.	3 oz.

Both mixtures worked perfectly in both the dry press and stiff mud machines. Several lengths of two hole conduits were expressed without showing signs of cracking or tearing.

All pieces dried safely, and showed that the salt had overcome the cracking entirely, but appeared to have no appreciable effect on reducing the drying shrinkage. A thin "greenish yellow" scum with a salty taste occurred on the surface.

The brick were burned to cone 9 in 52 hours and cooled in 36 hours. None of the stiff mud brick of either mixture were cracked. The dry press brick of B-55 were also sound while about 10% of the A-55 dry press brick showed minor cracks. The scum which occurred during drying had formed brown stains on the dry press brick and a brown glaze on the stiff mud brick. The glaze was thicker, glossier and darker on brick containing G-8 kaolin than on those containing kaolin G-35. The brick were well vitrified and showed a high shrinkage. The total shrinkages are as follows:

Total Linear Shrinkage	
A-55, stiff mud.....	11.27%
B-55, stiff mud.....	11.76%
B-55, dry press.....	7.25%
A-55, dry press.....	(not determined)

The Addition of Sand

Quartz sand is instrumental in reducing shrinkage because of its volume changes. A mixture of 85% quartz sand and 15% ball clay will expand approximately $^1/_2$ inch in 12 inches when burned to cone 9. Therefore, burning shrinkage can be controlled within limits depending upon three factors:

1. Minimum clay content necessary for bonding strength and molding properties.
2. Minimum flux content necessary to control the degree of vitrification.
3. Maximum sand content permissible without danger of "checking" or "cracking" during burning.

The next lot of brick were made from a mixture consisting of 35% kaolin (G-8), 52$^1/_2$% aplite and 12$^1/_2$% quartz sand. Part of the brick were made dry press and the remainder were molded in the auger machine. Even with such a low kaolin content, the column issued from both the brick and conduit dies as near perfect as one would desire, indicating the remarkable molding properties of the kaolins.

The dry press and part of the stiff mud brick were thoroughly dry when set but part of the stiff mud brick still contained some moisture after 24 hours' drying in a gas fired drier. No cracking occurred during drying. The brick were burned in 54 hours to cone 9 and cooled in 36 hours. No cracked brick resulted from the burning or the rapid cooling. The addition of sand reduced the shrinkage appreciably, inasmuch as the brick were three-sixteenths of an inch longer than those previously made without sand. The total shrinkage of the stiff mud brick was 9.76%, a reduction of 2% over brick to which no sand was added. The total shrinkage of the dry press brick was 6.28%, making a reduction in shrinkage of 1.97%. Brick which were bone dry when set were light gray in color while those which were damp when set were "pink-gray." There was some indication that this color may have been due partly to scumming.

Six of the dry press brick and twelve of the stiff mud brick in the leather hard condition were shipped to the Fisk & Company plant at Darlington, Pennsylvania, where they were dried and set in the top of a round down draft kiln fired with natural gas and burned to cone 10 in 6 days. The brick were well vitrified and light gray in color. The total shrinkage was 9.8%.

Increasing the Sand and Adding $BaCO_3$

In the final lot of brick made, the sand content was increased to 18%

and 2 oz. of $BaCO_3$ added to 100 lbs. of the mixture. Mixtures were made using both kaolins separately and also the two mixed in equal parts. The compositions were as follow:

No.	Kaolin G-35	Kaolin G-8	Aplite	Sand	$BaCO_3$
A-18	38 lbs.	....	44 lbs.	18 lbs.	2 oz.
B-18	....	38 lbs.	44 lbs.	18 lbs.	2 oz.
AB-18	19 lbs.	19 lbs.	44 lbs.	18 lbs.	2 oz.

The foregoing work demonstrated that such mixtures worked successfully in both dry press and stiff mud processes, and inasmuch as the stiff mud process appeared to be satisfactory in every way for these kaolins, and is therefore preferable, no dry press brick were made from the above three mixtures.

All three mixtures worked perfectly in both the brick and conduit dies. No cracking was observed during drying. The brick were set bone dry and burned to cone $8^1/_2$ in 50 hours, and cooled in 40 hours. A few of the A-18 brick cracked slightly during burning though this was not serious. None of the B-18 or AB-18 brick were cracked. The A-18 brick were light cream-gray while the B-18 brick were a little darker in color. The brick from all three mixtures were lighter in color than those previously made during these experiments. Evidently the improvement in color was due partly to the lower burning temperature and partly to the influence of the barium carbonate. The structure of the brick appeared to be dense though not thoroughly vitrified. The linear shrinkages of the three compositions were as follows:

	Drying shrinkage, per cent	Burning shrinkage, per cent	Total shrinkage, per cent
A-18	2.10	5.74	7.84
B-18	2.39	5.45	7.84
AB-18	2.25	5.61	7.86

The addition of sand made no appreciable difference in the drying shrinkage but reduced the burning shrinkage materially. The burning shrinkage was nearly 4% less than that of brick made without sand.

Conclusions

The foregoing results indicate that light cream and light gray face brick can be made from Georgia kaolin, aplite and sand. These brick compare favorably with the best face brick made from the fire clays of the Freeport, Mercer and Kittanning formations.

These kaolins are so plastic that mixtures containing as low as 35% kaolin to 65% non-plastic material mold readily by the stiff mud process. The stiff mud process is entirely satisfactory for such mixtures and is therefore preferable to the dry press process.

The so-called "soft" kaolins are friable and have low dry strength and are susceptible to cracking in drying and burning.

The so-called "hard" kaolins are the most desirable for brick making purposes. They have good bonding power and dry strength and will dry and burn without cracking.

Cracking during drying and burning of the soft kaolins can be eliminated by the addition of salt. If too much salt is added, it causes an efflorescence, brings soluble iron salts to the surface which develop into a brown discoloration or even a glaze on burning. The cracking caused by the soft clay can be overcome best by the addition of hard clay as was demonstrated in mix No. AB-18, a case of the "strong supporting the weak."

It has been demonstrated that such brick can be burned safely to cone 8 to 9 in 36 to 54 hours in a test kiln holding 200 bricks.

Brick containing 50% or less of kaolin when set bone dry offer no serious water smoking problem. They contain no carbon, pyrite nor other oxidizable matter, therefore, have no oxidation period; hence the burning can be carried on rapidly.

It is safe to say that a down draft kiln of seventy to eighty thousand bricks can be burned practically and economically in 3 to $3^1/_2$ days and cooled in a like period of time.

Raw Materials Available

The area along the lower edge of the Piedmont Plateau containing aplite low in iron and high in fluxes is in close proximity to the vast deposits of kaolin and white sand along the northern border of the Coastal Plain. These raw materials available for the manufacture of high grade face brick are sufficient to support a very large industry indefinitely.

Quarrying, transportation and grinding of the aplite rock will, of course, add to the production cost. As compared to face brick made from fire clays obtained by underground mining, the added cost of the flux is compensated for by the lower cost of mining the kaolin and sand by steam shovel.

There are several known areas of from 100 to over 600 acres in extent, underlaid with kaolins from 15 feet to over 40 feet in thickness. The overburden is comparatively light.

Fuel costs are higher in the kaolin districts than in the fire-clay areas, but the extra fuel cost is overbalanced by cheaper labor and the shorter burning time permissible with the kaolin mixtures.

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THE PROBLEM OF HEAT ECONOMY IN THE CERAMIC INDUSTRY[1]

By Willi M. Cohn[2]

Introduction

The ancient arts have recently been included in and elaborated by technical science. Scientific investigation of the several fields has begun at the same time. Such a development, by no means final, may also be observed in the field of ceramics.

Operations in former periods were exclusively such that each factory or small shop used its own secret and carefully guarded methods and processes. Present-day practices show a departure from this. To make possible any scientific findings in the field of ceramics, an extensive publicity of the methods of operation and experience of the individual concerns is absolutely necessary. Not until then can science react helpfully upon practical problems.

Investigation methods of chemical science especially those of the chemistry of silicates and of colloids, of physics and of physical chemistry have been applied for clarifying the manifold phenomena in the field of ceramics. A considerable advance has been made in scientific ceramic investigation. A comprehensive summary of the results obtained from such investigations has been given by Rieke.[3]

The Significance of Heat Economy for the Pottery Industry

The greatest consumption of heat in the ceramic industry occurs in firing the products.

A considerable number of kiln-constructions have been designed for obtaining the maximum utilization of heat. For the special solution of this and other problems dealing with Heat Economy, the German Ceramic Society has founded the Bureau of Heat Economy. Its objects, according to Reutlinger,[4] are to produce high grade wares with (1) the least possible percentage of waste, (2) suitable fuels, (3) the least fuel consumption and (4) a minimum period of firing. Accordingly the scope of the Heat Economy Bureau is primarily:

[1] A Dissertation submitted to the "Technische Hochschule" of Berlin in partial fulfillment of the requirements for the degree of Doctor of Engineering. Approved: April 18, 1923. Examiners: Professor Dr. Rieke, Professor Dr. Ing. Kloss.

[2] Dipl. Eng., Berlin.

[3] R. Rieke, "Neuere Fortschritte auf dem Gebiet der keramischen Chemie," *Fortschr. d. Ch. Phys. usw.*, 6 (1912).

[4] E. Reutlinger, "Wärmewirtschaftliche Untersuchungen an Brennöfen," *Ber. d. deutsch. keramischen Gesell.*, **2**, 2 (1921).

Editorial Note: Received October 15, 1923, in German text through courtesy of Dr. R. B. Sosman and translated by us for appearance in this *Journal*.

See Louis Navias, "Measurement of the Heat Absorbed and Evolved by Clays during Firing and Cooling," *Jour. Amer. Ceram. Soc.*, **6** [12], 1268 (1923). Dr. Cohn did not have opportunity to read the contribution by Dr. Navias.

(1) Detailed examination of the present working methods to discover existing defects.

(2) Devising means for improvement, and training of firing and operating personnel.

(3) Supervising of application and continuance in practice.

(4) Investigation of the science fundamentals which are basic to exact knowledge of the heat requirements in industrial ceramic firing.

Heat Requisite for Firing Ceramic Wares

The heat requisite for firing ceramic products and inducted into the kiln is utilized as follows: (1) One part is consumed in obtaining the necessary maturing temperature. The higher the maturing temperature the more heat is required. Efforts are being made to get the same results with a lower degree of temperature.

(2) In the case of the finer grades, the articles during firing are placed in saggers which must also be brought to this high temperature and therefore require a considerable expenditure of heat.

(3) Another portion of the inducted heat serves to furnish the heat requisite for the reactions which absorb heat during the firing. It is also decreased by the quantity of exothermal reactions which, of course, are not considerable.

(4) The remainder of inducted heat is used in warming the walls of the kiln, in obtaining a satisfactory draft and in covering the losses due to radiation and conduction.

With ceramic materials not only the temperature but also the time of reaction plays an important part, as has been shown by the investigations of Rieke.[1] In this case also the consumption of fuel is essentially affected.

To obtain the finished product from the unfired mass only a portion of the inducted heat is utilized. What this amounts to can only be determined from a heating chart, and only on the basis of such charts can we make any recommendations for improving present conditions. Some attempts at preparing heating charts have already been made; but as yet the most important basic data are lacking, *viz.*, *specific heat*, and the extent of *heat change*[2] occurring during the firing.

The investigation here submitted purposes to fill this gap. It aims to determine specific heat and heat changes for the materials employed in ceramics at the usual temperatures—in great part at very high temperatures—and thus to establish the lacking groundwork. We shall first discuss previous attempts at establishing these values.

[1] R. Rieke, "Brenndauer und Brenntemperatur in ihrer Wirkung auf die Konstitution und Mikrostruktur des Porzellans," *Ber. d. deutsch. Keram. Ges.*, **2**, 2 (1921).

[2] EDITORIAL NOTE: Wärmetönung, a difficult word to translate. It is the general term covering *heat of reaction, heat of fusion, heat of inversion,* etc. Throughout this treatise the author's use of the word "Wärmetönung" has been translated as "heat change" which admittedly is not sufficiently comprehensive.

Previous Methods for Determining "Specific Heat" and "Heat Change"

Frankenheim Heating and Cooling Curves

The so-called Frankenheim heating and cooling curves were devised to ascertain the behavior of a solid body during firing. The material to be tested, contained in a crucible, was placed into an electric furnace. At stated intervals, as frequently as possible, the temperature of the mass was read. Thus was obtained a *curve of temperature as a function of time.*

By comparing the temperature-time curve for the substance with that for the empty furnace it is possible to draw conclusions as to the behavior of the mass during firing. If there is a falling off in the temperature of the substance as compared with the temperature of the furnace, then a heat consuming process is taking place within the mass itself. If, on the other hand, the temperature advances, the process is one in which heat is liberated.

This method of thermal analysis has been applied to the chemistry of silicates by Tammann[1] and by the Geophysical Laboratory at Washington.[2]

Heating and Cooling Curves for Silicate Reactions

With reversible reactions it is immaterial whether the heating or the cooling curves are made, for in each the degree of temperature and the time of the reaction coincide.

The irreversible processes, as with silicates, show an entirely different behavior. In making cooling curves for silicates, strong under-coolings occur which may mount up to 150°C. Cooling curves for the silicates are therefore not admissible. Jaeger,[3] on this point, states as follows:

> The method of cooling (measured as a function of time), and the fixing of specific temperatures by means of discontinuities in the curve due to heat changes, fails absolutely within most silicates because of the slowness in reaching a condition of equilibrium. In spite of the very marked undercoolings and retardation which usually occur, Tammann's method for determining the duration of heat effects continues to be employed in obtaining fusion diagrams, and scarcely is it even suspected that under such circumstances this process is senseless and absolutely inadmissible.

Then, too, with too rapid a rate of heating the temperatures at which the reactions are observed to occur are above the required minimum as has been shown by Doelter[4] and Meissner.[5]

[1] G. Tammann, "Kristallisieren und Schmelzen," Leipzig: Barth (1903).

[2] A. L. Day, "Die Untersuchung von Silikaten," *Z. f. Elektroch.*, 17 (1911).

[3] F. M. Jaeger, "Eine Anleitung zur Ausführung exakter physiko-chemischer Messungen bei höheren Temperaturen," Groningen: J. B. Wolters (1913).

[4] Doelter, "Physikalisch-Chemische Mineralogie," Leipzig: Barth (1905).

[5] B. Meissner, "Studien über Schmelz- und Umwandlungserscheinungen," Diss. Göttingen (1920).

Simultaneous Heating with Reference Substance

Satoh[1] in his investigations of Japanese kaolin proceeded according to the differential method suggested by White[2] and developed by Dittler.[3] The substance to be studied was heated simultaneously with a reference substance of known behavior. Unfortunately he chose quartz sands as the reference body, and failed to observe that its transformations at 575° and 800° should have appeared on the curves and should have been considered.

Standardized Rate of Heating

Friedrich[4] on the basis of the temperature-time curve established a heating-rate curve in order to show more clearly the behavior of a substance during heating. With the aid of a specially constructed regulating rheostat he was able to control the heating of the furnace in such a way that the rate of heating was uniform throughout the process.

These investigations were designed to give exact temperature-time curves, character of heat effects occurring, and temperature at which the reactions occur. However, they give no information as to the magnitude of the heat changes.

Heat of Crystallization

Tammann's process[5] has already been referred to, and its inadequacy noted. Vogt[6] is still employing it; but Plato,[7] in order to avoid undercooling uses inoculation thus obtaining an agreement in the fusion and solidification points. From the values obtained he calculates specific heat and heat changes. Koenigsberger[8] would determine heat changes from an extrapolation of cooling-curves according to definite assumptions, a procedure which cannot be applied to the silicates.

Another method was employed by Roos.[9] He charted cooling-curves of two substances, one of which has a known fusion and reaction heat.

[1] S. Satoh, "A Study of the Heating and Cooling Curves of Japanese Kaolinite," *Jour. Amer. Ceram. Soc.*, **4** [3], 182 (1921).

[2] W. P. White, "The Thermoelement as a Precision Thermometer," *Phys. Rev.*, **31**, 2 (1910).

[3] Dittler, "Beitrag zur Thermochemie der Silikate," *Z. f. anorg. Ch.*, 69 (1911).

[4] K. Friedrich, "Über ein einfaches Verfahren zur ersten Orientierung beim Studium der thermischen Dissociation und der Konstitution leicht zerlegbarer Mineralien," *Zentralblatt f. Min. usw.* (1912).

[5] G. Tammann, *loc. cit;* K. Hüttner und G. Tammann, "Über die Schemlzpunkte und Umwandwandlungspunkte einiger Salze," *Z. f. anorg. Ch.*, 43 (1905).

[6] J. H. L. Vogt, "Die Silikatschmelzlösungen," Christiania (1903).

[7] W. Plato, "Erstarrungserscheinungen an anorganischen Salzen und Salzgemischen," *Z. f. physikal. Ch.*, 55 (1906), 58 (1907).

[8] J. Koenigsberger, "Einfache Methode zur Bestimmung von Wärmetönungen bei Silikaten usw.," *Zentralbl. f. Min. usw.* (1912).

[9] D. Roos, "Über die Schmelzwärme und die Bildungswärme von Metallverbindungen usw.," Diss. Gött. (1916), *Z. f. anorg. Ch.*, 94 (1917).

By comparing the two curves he determined the heat variations of the body to be investigated.

Evaluation of Temperature-Time Curves

For evaluating the temperature-time curves White[1] proposes that the heat inducted into the material in a small, experimental, electrical furnace is proportional to the difference in temperature between furnace and material (G) to the time of action (Z) as well as to a constant (K) which he designated as "heat flow factor" or "radiation factor." G and Z can be determined. K may be dependent upon G and may vary with temperature, although this variation may not be determinable by experiment. Consequently G had better be held constant.

Thermal Microscope

Other investigators worked with the thermal microscope first constructed by Doelter.[2] The material to be tested was placed in a small electric furnace. The transformation temperatures could then be determined optically from the behavior of the material. This method has been used chiefly in physico-chemical petrography. Investigations which are of interest in ceramics were conducted by Mellor and Holdcroft,[3] Dittler,[4] Mellor,[5] also by Nacken.[6] Boeke[7] made use of the thermal microscope even under high pressure.

Microscopic Study of Powders

Bowen[8] was one of the first who worked the method now generally employed for silicates. The test substance is brought to a definite temperature and kept at this for a period—in some cases for several days—then quenched or chilled and microscopically examined. By narrowing down the intervals it is possible to determine with exactness the point of fusion.

Calorimetric Methods

Akerman[9] and his followers determined the heat of fusion of several substances by calorimetric methods. The apparatus used was primitive and their calculations vitiated by errors, some of them being considerable.

[1] W. P White, "Schmelzpunktsmethoden bei hohen temperaturen," dto.

[2] Doelter, *loc. cit.*

[3] Mellor and Holdcroft, "The Chemical Constitution of the Kaolinite Molecule," *Trans. Ceram. Soc.* (English), 13-14 (1910-11).

[4] Dittler, *loc. cit.*

[5] Mellor, "Glazes in the Glost Oven," *Trans. Ceram. Soc.* (Eng.), 1912-13.

[6] R. Nacken, "Bestimmung der Schmelztemperaturen von Silikaten auf optischen Wege," *Silikat Zts.* (1913).

[7] H. E. Boeke, "Die Schmelzerscheinungen und die umkehrbare Umwandlung des Calcium Carbonates," *Neues J. f. Min. usw.*, 1 (1912).

[8] Bowen, "Schmelzerscheinungen bei den Plagioklas-Feldspaten," *Z. f. anorg. Ch.*, 82 (1913).

[9] Akerman, "Über die zum Schmelzen verschiedener Hochofenschlacken erforderliche Wärmemenge," *Stahl u. Eisen* (1886).

Heat of Solution

Another indirect method for determining heat changes which heretofore had been used primarily for the determination of fusion heat is based on the application of the first law of thermodynamics to chemical reactions. According to this the change in the energy of a body is independent of the manner in which it occurs.

The fusion-heat of a body is determined by dissolving its crystalline form in a given solvent and measuring the "heat of solution." The same body in a melted or amorphous (under-cooled) state is then dissolved in the same solvent and its heat of solution is established. Subtracting the two solution-heat values gives the heat of fusion or crystallization. In an analogous manner the other heat changes are determined.

Le Chatelier (summarized)[1] made use of this method and, after him, a whole series of investigators, one of them being Mixter.[2] It was applied by Mulert[3] to the chemistry of silicates especially quartz and several metallic silicates. The great difficulty, however, was in finding a suitable solvent for the silicates. He made use of a 20% hydrofluoric acid by which quartz and the metallic silicates could be dissolved within a period of 20 minutes. If the time necessary for dissolving is too long, the heat of solution in the calorimeter cannot be determined with necessary accuracy because of the rapid equalization of temperature between the calorimeter and its environment. Mulert even had some difficulty in dissolving pure alumina. With the double silicates of alumina he was able to calculate the requisite values, but he was unable to dissolve kaolin in sufficiently short time. Another large series of experiments was made by Heinrich.[4] He attempted to dissolve silica in hydrofluoric acid; but he was unable to secure complete solution.

The writer also first intended to determine the heat changes of ceramic materials according to Mulert's process. Numerous experiments were made with hydrofluoric acid of various concentrations; also with a mixture of hydrofluoric, hydrochloric and sulphuric acids in varying concentrations and proportions. An attempt was also made to bring about solution by heating the solvent. All these attempts, however, showed the impossibility of finding a suitable solvent in which fired porcelain, and the like, could be dissolved. With Portland cement matters are quite different.

[1] Le Chatelier, "La silice et les silicates," Paris: Herman (1914).

[2] Mixter, "Bildungswärme und Polymerisation einiger Oxyde," *Z. f. anorg. Ch.*, 92 (1915).

[3] O. Mulert, "Über die Thermochemie der Kieselsäure und der Silikate," Diss. Göttingen (1912).

[4] K. Heinrich, "Über die in Flusssäure lösliche Modifikation des Siliciums," Diss. München T. H. (1919).

Nacken[1] succeeded in dissolving the cement by a mixture of hydrochloric and hydrofluoric acids. Thus he furnished the basis, up to then lacking, for the study of cement firing.

We have shown that with none of the previously used processes was it possible to determine experimentally the heat changes that occur during the firing of ceramic materials.

Specific Heat

Quite a number of processes for determining specific heat have been worked out. Tabulations can be found in Kohlrausch,[2] Burgess and Le Chatelier,[3] Stähler[4] and in many other places. The substance heated to a certain temperature, falls into a calorimetric vessel which has been filled with a liquid or is composed of a good heat conductor. The rise in temperature in the calorimeter is read, and the specific heat calculated for that definite temperature of the specimen. In this manner, taking point after point, it is possible to determine the change in specific heat. According to the investigations of Nernst and his collaborators[5] the specific heat of solid bodies near the absolute zero point is zero; it increases with temperature; the maximum value of the product of the atomic weight and of specific heat is about 6.4. According to the experiments of Richarz[6] and others, specific heat in the neighborhood of the fusion point assumes abnormally high values; this being caused by the fact that in these values, to a great extent, the fusion heat is included.

With silicates, and especially with ceramic materials, only a small number of investigations have been made. A method has been developed for silicates by White.[7] He employs an electric furnace placed directly above the calorimeter. After the test specimen has reached a definite temperature, it is dropped into the water of the calorimeter. In a similar manner Heyn, Bauer and Wetzel[8] examined a large number of fired fire-clay materials at temperatures as high as 1200°C.

[1] R. Nacken, "Thermo-chemische Untersuchungen am Zementrohmehl und am Zement," *Zement* (1922).

[2] F. Kohlrausch, "Lehrbuch der praktischen Physik," Leipzig: Teubner (1910).

[3] Burgess and Le Chatelier, "Die Messung hoher Temperaturen," Berlin: Springer (1913).

[4] A. Stähler, "Handbuch der Arbeitsmethoden der anorganischen Chemie," 3, 1; Leipzig: Veit (1913).

[5] W. Nernst, "Die theoretischen und experimentellen Grundlagen des neuen Wärmesatzes," Halle: Knapp (1918); "Theoretische Chemie," Stuttgart, Enke (1921).

[6] F. Richarz, "Die Theorie des Gesetzes von Dulong und Petit," *Z. anorg. Ch.*, **59**, 59 (1908).

[7] W. P. White, "Specific Heats of Silicates and Platinum," *Amer. Jour. Sci.*, 28 (1909).

[8] E. Heyn, O. Bauer, E. Wetzel, "Untersuchungen über die Wärmeleitfähigkeit feuerfester Baustoffe," *Mitteil. aus. Königl. Materialprüfungsamt*, 2-3 (1914).

Other experiments were made with the copper calorimeter suggested by Nernst;[1] *e. g.*, the experiments of Magnus,[2] Drägert[3] and Steger.[4] These investigations, however, were confined to a few temperatures only. They give, therefore, but an incomplete picture of the behavior of ceramic materials during firing.

An examination of the specific heat of ceramic materials used in factories under all requisite temperatures is still lacking. Such a determination made by the method of mixtures cited above, with the aid of calorimetric experiments would require an immense amount of time and labor.

The impossibility of determining the heat changes as well as the difficulties in determining specific heat, have led the author to seek a process which makes possible a simple determination of the values referred to, and he believes he has found it in the process here to be described.

The Theory for a New Process for Directly Determining Specific Heat and Heat Changes

In order to determine specific heat (as well as the heat changes) directly in a given material, the temperature-heat-energy curve of this material must be known.

This curve, dependent upon temperature t, indicates what amount of heat is inducted into the weight-unit of the material. In the following, 1 gram (g) is taken as a unit of weight, and the quantity of heat is measured in small calories (cal); the quantity of heat inducted into the unit of weight is designated q and is measured cal/g. The determination of the values to be established proceeds as follows:

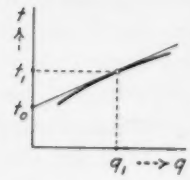


FIG. 1.

1. Specific Heat

In order to determine the true specific heat at a given temperature t_1 from the temperature-heat curve the tangent is drawn at the point in question in this curve (Fig. 1). The following equation then holds for the true specific heat C_w

$$C_w = \frac{q_1}{t_1 - t_0}$$

[1] W. Nernst, *loc. cit.*

[2] A. Magnus, "Über die Bestimmung spezifischer Wärmen," *Ann. d. Phys.*, 31 (1910), *Phys. Zeits.*, 14 (1913).

[3] W. Drägert, "Thermodynamische Untersuchungen am Calciumhydroxyd, sowie über die graphische und mechanische Berechnung chemischer Affinitäten aus thermischen Messungen," Diss. Berlin U. (1914).

[4] W. Steger, "Über die mittlere spezifische Wärme einiger keramischer Massen in zwei verschiedenen Temperaturbereichen; Über die spezifische Wärme feuerfester Erzeugnisse," *Sil.-Z.*, **2** (1914).

2. Heat Changes

The heat changes occurring, which are conditional upon the transformations within the mass itself, show on the q-t curve. If the reaction takes place with great rapidity, the heat-absorbing reactions show as portions of the curve parallel to the q-axis. (Fig. 2.) Those reactions in which heat is set free appear as breaks in the otherwise even q-t curve. (Figs. 2 and 3.) In Fig. 2 the length of a-b gives directly the value of the heat absorbing reaction.

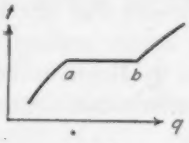


FIG. 2.

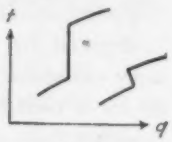


FIG. 3.

Determination of Inducted Heat

The difficulty now lies in determining experimentally the inducted heat, as requisite for the establishing of the q-t curves. This difficulty has already been pointed out by Jaeger[1] and White.[2]

Given the test substance S in a crucible T placed in an electric furnace O (Fig. 4) whose temperature is to be measured with the aid of thermoelement E. Let the thermoelement be placed exactly in the middle axis of the crucible halfway down into the substance. The heat, which is produced continuously in the furnace walls is transferred to the crucible through the air in the furnace, then penetrates the wall of the crucible and is conducted through the test-material to the junction points of the thermoelement. The quantity of heat inducted into the test material is then dependent upon:

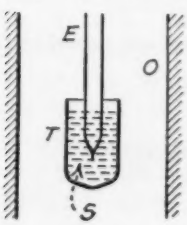


FIG. 4.

1. The degree of temperature prevailing in the furnace
2. The amount of heat transference by the layer of air in the furnace between the furnace wall and the crucible
3. The amount of heat penetration of the crucible material
4. The heat conductivity of the test material
5. The duration of the induction of heat.

Heat Conductivity of Test Material

The heat conductivity of the test material depends upon the kind of substance but varies within a narrow range at stated temperatures with ceramic materials. The earliest investigations for determining it were made by Paalhorn[3] and Hecht.[4] The materials specifically used in

[1] F. M. Jaeger, *loc. cit.*

[2] W. P. White, "Schmelzpunktsbestimmungen," *Z. f. anorg. Ch.*, 69 (1911); *Amer. Jour. Sci.*, 28 (1909).

[3] O. Paalhorn, "Über die Wärmeleitung verschieden zusammengesetzter Gläser," Diss. Jena (1894).

[4] H. Hecht, F. E. Neumanns, "Methode zur Bestimmung der Wärmeleitfähigkeit schlecht leitender Körper in Kugel- und Würfelform," Ph. Diss. Königsberg (1903).

ceramics were treated by Nusselt,[1] Rinsum,[2] Goerens,[3] Knoblauch, Raisch and Reiher,[4] and other investigators. These investigators worked mostly at low temperatures; but Wologdine[5] worked with a considerably higher temperature and showed that the heat conductivity of all materials investigated by him hovers around a common median value. Also the very extensive tests by Heyn, Bauer and Wetzel[6] show that the conductivity of heat of similarly constituted materials at the same temperature does not vary much.

Wetzel shows the increase of heat conductivity with increasing temperature, and this occurs in a similar manner in all materials. The results of these investigations are summarized in the "Sprechsaalkalendar."[7]

Simonis[8] is of the opinion that the conductivity ascertained for ceramic materials of varying composition but of similar porosity does not represent the conductivity of the materials but of the air contained within them.

Furnace Characteristic

It is thus possible to refer all the values requisite for the determination of heat q inducted into the material to:

1. The degree of the prevailing temperature, t
2. The amount of difference in temperature between furnace walls and crucible, G
3. The duration of induction of heat z, the relations being:

$$q = f(t,G,z).$$

The quantity of heat inducted into the crucible per unit of time is:

$$\frac{dq}{dz} = f_1(t,G)$$

dq/dz is thus dependent only upon t and G. If this function has once been established for a particular furnace then it holds good under absolutely similar test conditions *for all materials* of similar composition and heat conductivity. This could then be designated as the "furnace characteristic."

[1] W. Nusselt, "Die Wärmeleitfähigkeit von Wärmeisolierstoffen," Diss. München, T. H. (1908).

[2] W. van Rinsum, "Die Wärmeleitfähigkeit von feuerfesten Steinen bei hohen Temperaturen usw.," Diss. München, T. H. (1914).

[3] P. Goerens, "Über die Wärmeleitfähigkeit feuerfester Steine;" Ber über 34. Hauptvers. d. Ver. dtscher. Fabr. feuerfester Prod., Berlin, *Tonindustrieverlag* (1914).

[4] O. Knoblauch, E. Raisch, H. Reiher, "Wärmeleitzahl für Bau- und Isolierstoffe usw.," *Gesundheitsingenieur*, 43 (1920); Ref. *Das Gas- und Wasserfach*, 64 (1921).

[5] Wologdine, "Untersuchungen über die Wärmeleitfähigkeit, Porosität, und Gasdurchlässigkeit der feuerfesten Materialen," *Sprechsaal*, 1909.

[6] Heyn, Bauer and Wetzel, *loc. cit.*

[7] "Sprechsaalkalender," Coburg: Müller & Schmidt (1922).

[8] M. Simonis, "Beitrag zur Bestimmung der Wärmeleitfähigkeit von Chamotte Ziegeln, etc.," *Sprechsaal* (1908).

Determination of Furnace Characteristic

For the purpose of determining the *characteristic of a furnace* the knowledge of q is essential for some given material; q depends upon temperature as does the true specific heat c_w. Both values are related as follows:

$$dq = c_w.dt$$

If, then, by any process c_w has been established for a given substance in relation to temperature, then q (expressed in cal/g) can be calculated.

If, by experiment, a temperature time (t-z) curve is established for the same material for which q has been determined, then the two curves may be converted into one. We then obtain from the q-t and the t-z curves a q-z curve. By differentiation of this curve a dq/dz curve can be established in its dependence upon z or t, respectively. Should G be considered constant during the experiment then the last-named curve holds only for this one definite G. Thus we have met the conditions and have found for the furnace in question:

$$\frac{dq}{dz} = f_1(t,G)$$

A similar curve may also be made for another G, enabling us to finally obtain a curve chart of the furnace characteristic, from which dq/dz may be read for any temperature or temperature gradients in furnace walls and crucible.

To establish a temperature-heat-energy curve for any kind of material which falls under the aforementioned conditions, from which the specific heat and heat changes must result indirectly, it is necessary to construct the curves for temperature and temperature differences, dependent upon time, for such material according to the established test-conditions. From this we establish the dq/dz curve with the aid of the furnace characteristic. By integration we find the q-z and then the desired q-t curve.

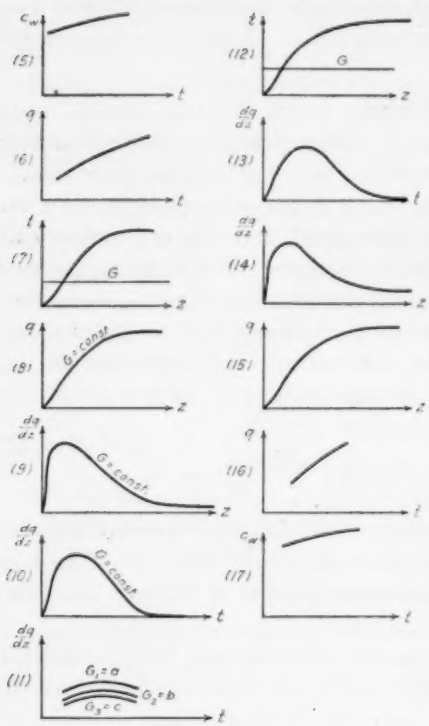
Summary

The steps for determining the unknown quanti ties which are necessary for the study of heat economy are:

A. Calorimeter tests for the determining of q.
   1. Determining specific heat as a function of temperature (experiment) c_w-t curve (Fig. 5).
   2. Calculations of the inducted heat as a function of temperature; q-t curve (Fig. 6).

B. Determining the furnace characteristics on the basis of the same material as used for "A."
   1. Making a temperature-time curve with constant temperature gradients between furnace-wall and crucible. (Experiment): t-z curve (Fig. 7).

2. Determining the q-z curve for a constant G (graphically) (Fig. 8).
3. Differentiation of the q-z curve (Interpolation calculation after Thiele[1] and Sanden[2] $\frac{dq}{dz}$-z curve) (Fig. 9).



FIGS. 5–17.

4. Determining the $\frac{dq}{dz}$-t curve with a constant G (graphically) (Fig. 10).
5. Making a curve chart by determining corresponding curves for a varying G (Fig. 11).

C. Determining the q-t curves of various materials.

1. Making t-z curves for various substances with a constant G (Fig. 12).
2. Determining the $\frac{dq}{dz}$-t curves from the curve charts (Fig. 13).
3. Determining the $\frac{dq}{dz}$-z curves (Fig. 14).
4. Graphic integration for determining the q-z curves (Fig. 15.)
5. Making the q-t curve for the material in question (Fig. 16.)

Furnace Characteristics Determined from t-z Curves

The finding of furnace characteristics can also be done in a somewhat different manner. During the investigations it has appeared that it is generally impossible to control the heating of the furnace sufficiently to keep the temperature gradient between furnace wall and crucible constant at a given temperature. Theoretically, also, it does not seem possible to have G constant during the experiment as has been shown by White.[3] The making of a curve chart was therefore attempted on the following considerations:

The same curve chart, "furnace characteristics," will also be obtained if G is known for every point of the t-z curve, as well as for the curves developed therefrom. Consequently, if for the same substance several $\frac{dq}{dz}$-t curves have been determined, and points with a coinciding G are joined, we obtain the same curve chart as above (Fig. 18).

If in these experiments more than 1 g. of the substance is used—as is here assumed—it will have to be considered for the furnace characteristic.

[1] T. N. Thiele, "Interpolationsrechnung," Leipzig: Teubner (1909).

[2] H. v. Sanden, "Praktische Mathematik," Berlin: Urban (1920).

[3] *Loc. cit.*

D. Determining the specific heat for the various temperatures (according to Fig. 1) for the test material (Fig. 17).

E. Determining the extent of the occurring heat changes (according to Figs. 2 and 3).

Experimental Arrangements for Determining the *t-z* and *G-z* Curves

The making of the temperature-time and temperature-difference time curves was done in the following manner:

The Furnace

A tubular resistance furnace with outside platinum foil winding[1] furnished by the Heraeus Company, was set up vertically. Its capacity was 14 amp.; 220 volts.

Maintenance of Zone of Uniform Temperature

The main difficulty with such types of furnace consists in obtaining and maintaining a zone of uniform temperature,[2] particularly with low temperatures. According to Ostwald-Luther[6] the most advantageous type of vertical furnace is one in which the furnace is completely closed at the top and where the removable cover is placed at the bottom.[7] By this arrangement air currents are almost entirely eliminated.

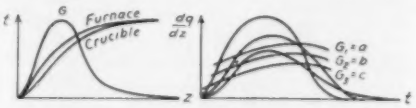


FIG. 18.

In order to obtain the maximum of temperature constancy the tubular furnace was closed below by several asbestos and fire-clay plates. On top was placed a close-fitting cover of fire clay in which were left the necessary openings for the protection tubes of the thermoelement, thereby shutting out the current of air except for the minimum that would enter through the cracks. It was actually shown that the zone of constant temperature remained almost always at the same point. The construction of the furnace is shown in Fig. 19.

[1] According to Bronn such types of furnace are quicker in action than those wound with platinum wire. Bronn, "Der elektrische Ofen im Dienste der keramischen Gewerke," Halle Knappe (1910).

[2] See Lucas;[3] Jaeger;[4] White.[5]

[3] Lucas, "Feuerschwindung," Diss. Göttingen (1903).

[4] F. M. Jaeger, *loc. cit.*

[5] W. P. White, *loc. cit.*

[6] Ostwald-Luther, "Physiko-chemische Messungen," Leipzig: Engelmann (1910).

[7] Lucas, Jaeger and White did their work in furnaces some of which were open from below and others but imperfectly closed. Naturally there arises a strong convection current making it difficult to obtain a zone of equal temperature. According to Ferguson (J. B. Ferguson "Temperature Uniformity in an Electric Furnace," *Phys. Rev.*, 12 (1918)) a perfectly uniform distribution of temperature can only be obtained in horizontal furnaces both ends of which are alike heated.

Maintenance of Temperature

The processes to be investigated require a maximum temperature of 1400°C which was easily obtained even though the winding was on the outside. The furnace was heated by a 220-volt direct current regulated exactly by resistance. The connections are indicated in Fig. 20. The apparatus was so arranged that the readings of an ammeter, as well as the regulating were easily accomplished from a sitting position.

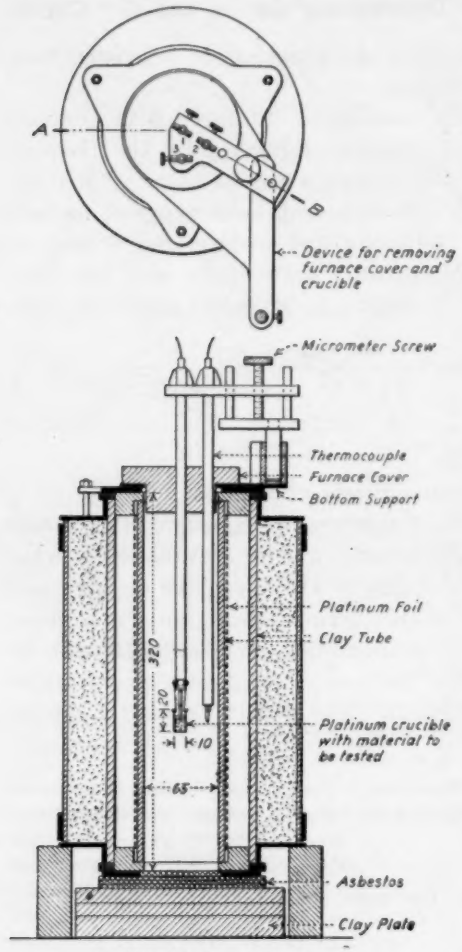


FIG. 19.

The Crucible

The test material was placed in a small crucible of iridium-free platinum, furnished by Heraeus. This crucible had the shape of a cylinder 10 mm. in diameter, 20 mm. in length, closed at the bottom. *Its capacity was about 2 g.*[1]

At the upper end of the crucible were three holes about 1 mm. in diameter 120° apart for the purpose of suspending the crucible. The crucible was filled almost up to the holes.

In order to avoid a loss of heat the crucible was not supported from below in the furnace but suspended on the thermoelement protection tube. (Cf. Fig. 19*a*.) In this manner, above all, we avoided having an opening in the bottom of the furnace.[2] By this arrangement it was possible to control absolutely the insertion of the thermoelement. It is of chief import to measure the tempera-

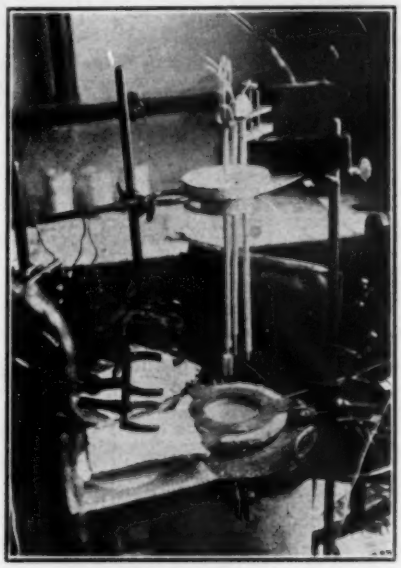
[1] This arrangement, like those of White, *loc. cit.* and Jaeger, *loc. cit.* purposes to minimize as much as possible the temperature difference between the center of the crucible and the crucible wall, as well as to exclude as much as possible the influence of variations in heat-conductivity of the test material.

[2] Contrast with Jaeger, who accomplished the suspension by cylindrical platinum sheets as connecting links between the protection tube and the crucible.

ture exactly at the medial axis of the platinum cylinder and exactly at half the height of the material. With this experimental apparatus[1] it is possible to actually observe the insertion of the thermoelement into the finely powdered mass.

Thermocouple

The thermocouples used were platinum-platinum 10% rhodium, by Heraeus, of 0.4 mm. thickness. According to Day and Sosman[2] such thermoelements at 1200° show a variation of ±1°C; at 1600° ±1.5°C. These measurements were generally made with the junction points unprotected.[3]



Before the experiment.
FIG. 19*a*.

In order to secure a more sensitive measurement the temperature difference between furnace and crucible was determined directly according to the differential method by juxtaposition of two thermoelements. Moreover, it was requisite to measure the degree of heat prevailing at any moment of time. We accomplished this by placing a third thermoelement into the furnace.

The two thermoelements for measuring the furnace temperature were equidistant from the center of the furnace; they were sufficiently distant one from the other so as not to interfere with each other in their registration.[4]

The junction points of each thermoelement extended about 7 mm.

[1] In consequence of the prevailing shortage of platinum it was not possible to construct a Faraday screen, so as to avoid disturbances in the thermoelement under extreme heat which causes ionization of the air. Disturbances of this sort, according to Jaeger, *loc. cit.* occur only at temperatures higher than 1400°, and chiefly in furnaces with inner coils. The limits of temperature of the measurements made by us generally were lower than that, so that an error can scarcely have occurred within this range.

[2] A. L. Day, R. B. Sosman, E. T. Allen, "High Temperature Gas Thermometry," *Carnegie Institution Publication*, 157 (1911).

[3] To determine the temperature gradient G between the furnace wall and crucible two thermocouples are necessary. See Bronn, *loc. cit.*, White, *loc. cit.*, Jaeger, *loc. cit.*

[4] In consequence of the individual conductivity of heat in each thermoelement it might otherwise have occasioned a lowering of temperature within its immediate environment; this would have disturbed the indications of the other element.

The three thermoelements were placed to form approximately an equilateral tri-

beyond the protection tube. To obtain an exactly parallel and permanently fixed position of the thermoelements they were carried over a considerable length by the cover. Above the cover was a contrivance which, by means of a micrometer screw, made possible from above a fine adjustment of the three thermoelements. It served the purpose of determining exactly the location of the zone of constant temperature and to adjust the thermoelements accordingly. The protection tubes at their upper ends had an offset which absolutely prevented their slipping down into the interior of the furnace. (Cf. Fig. 19.)

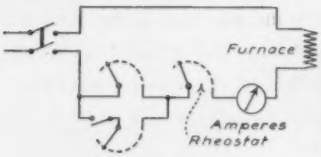


FIG. 20.

A special device which may also be observed in Fig. 19, made it possible to withdraw completely from the furnace both the cover, the thermoelements and the platinum crucible as well as to swing them aside so that the adjustment of the thermoelements and also their centering in the mass, etc., could be accomplished *outside* of the furnace. The whole could then again be lowered into the furnace. The free terminals of the thermoelements were placed in melting ice which was kept in double-walled vessels. The thermoelement serving for measuring the temperature of the furnace was connected directly through a moving-coil galvanometer.[1]

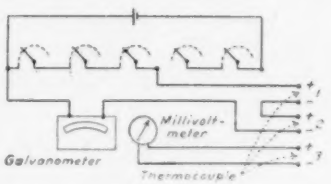


FIG. 21.

The two thermoelements in differential position were connected through a compensating device.[2]

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angle (in outline), its one corner being in the axis of the furnace. The exposed junction points of each element were on exactly the same level in the furnace.

This arrangement, when compared with that of Austen, and employed by Dittler, *loc. cit.* (2 thermoelements in the crucible, one outside of it) has the advantage that the thermoelements do not dissipate too much heat from the mass.

Furthermore, it is preferable to employ as reference temperature, the temperature of the furnace, which is always changing in the same way under similar test conditions, inasmuch as the crucible temperature constantly changes because of the reactions occurring during heating.

[1] Type Deprez-d'Arsonval (make: Keiser & Schmidt), sensitivity 10^{-4} amp.

[2] Type Poggendorff as indicated by Kohlrausch connected with a zero instrument (make: Siemens & Halske), sensitivity 3.10^{-7} amp. The connections can be seen in Fig. 21. The storage cell of the compensator was calibrated daily by comparing it with a normal element; compensation was made in the usual manner. The different temperatures were read by means of calibration curves in millivolts. The investigations with the compensation apparatus were made according to the detailed directions of Jaeger, *loc. cit.* On account of the limited funds available it was impossible to provide a Diesselhorst potentiometer, free from thermo-e.m.f.

Determining the t-z and G-z Curves

The Sample

In order to obtain measurements that are actually reproducible, the material must always have the same granularity as well as be of the same average composition.[1]

The materials were pulverized in large quantities and ground for eight hours in the porcelain mill. They were then put through a very fine lawn. The rest of the soft materials, such as kaolins and clays, were examined in the slimed state.

Operating the Apparatus

The test material was dried for two hours at 125°. Two grams were weighed out and placed in the platinum crucible. By proper shaking it was possible to so put the mass into the crucible that it always reached the same level—usually close to the holes made for suspending the crucible.

The crucible was then suspended—outside of the furnace—the thermoelement carefully inserted to proper depth exactly in the center of the crucible, then the whole was swung over the furnace and gradually lowered. The two other thermoelements had previously been carefully adjusted.

Preliminary Tests

The preliminary tests were to find the zone of constant temperature in the furnace. The furnace was kept at constant temperature for a considerable time. The thermoelements were raised and lowered and then by accurate adjustment with the micrometer-screw the desired region having a range of 45 mm. was determined. By several similar tests, under different temperatures, we checked up the location of this zone. Even during the tests frequent checks were made. From these it appears that this zone varied only within a few millimeters.

Rate of Heating

Wohlin[2] in making heating curves proceeded by gradually increasing the current which he used for heating the furnace. He increased the current every five minutes by $^1/_2$ amp. The curve resulting appears as a uniform slowly rising line. But when a curve of similar sort was made with our more exact testing device, it appeared that for each increase in the heat current there was a corresponding irregularity in the heating curve. This can be seen in Fig. 22. The upper curve shows the temperature of the furnace, the next

[1] Leitmeier, "Zur Kenntnis der Schmelzpunkte von Silikaten," *Z. f. anorg. Ch.*, 81 (1913), proposes that test material be finely pulverized in an agate mortar, slimed and the suspended part only be used. Such a process, of course, is exceedingly troublesome and time consuming; moreover it is probably not wholly free from objections since the particles of greater specific gravity settle on the bottom and thus escape examination (*e. g.*, quartz particles, etc.).

[2] R. Wohlin, "Beiträge zur thermischen Analyse von Tonen, Bauxiten und einigen verwandten Körpern," Diss. Breslau (1913).

lower that of the crucible; the lowest curve on a scale five times enlarged, shows the difference in the temperature of both—(G-z curve). If, on the other hand, the furnace temperature was but gradually increased the smaller heat effects were almost unobservable.

It had been stated that it was exceedingly difficult to conduct the heating so that G would remain absolutely constant during a test. It has also been known that this does not seem desirable, even from a theoretical

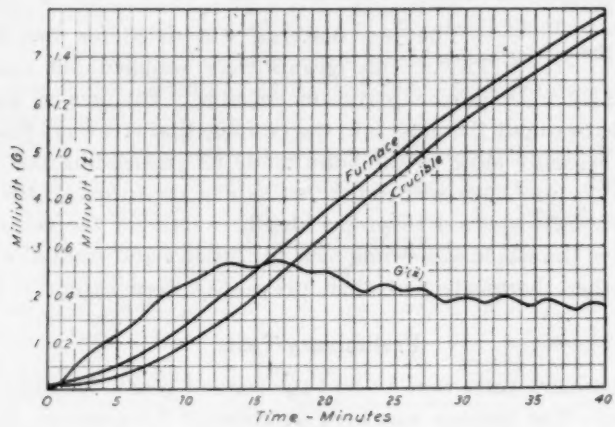


FIG. 22.

point of view. The irregularities occurring from this could only be ascertained by means of the differential method.

The numerous curves necessary for obtaining the curve chart dq/dz-(t_1.G) were obtained as follows: In one experiment a definite current of 14 amperes was switched on and the curve resulting was made without further regulation of the current. In another experiment a definite current was continued by *constant* regulation during the entire process. In both cases there resulted quite uniform curves, rising in the beginning, but subsequently declining gradually. With an energy supply constantly kept at 14 amp. and 220 volts (= 3080 watts) a temperature of about 1400°C could easily be obtained in about 90 minutes.

Readings were taken every ten seconds; alternately reading furnace temperature and temperature differences. Time was indicated by a clock striking every ten seconds.

(To be continued)

NOTE ON AN UNUSUAL CASE OF WARPING OF FLAT WARE IN THE GLOST KILN[1]

By Thomas A. Shegog

ABSTRACT

The warping of flat ware in the glost kiln can apparently be caused by the "pull" of a cooling glaze, provided the glaze solidifies before the body has become entirely rigid.

Seven-inch plates of the regular biscuit ware which had been fired to cone 8 half over, and which had an absorption of 7.5 to 9%, were dipped in a trial glaze by the regular dipper and fired for 22 hours in the second ring of the glost kiln. One bung of plates with this glaze was placed in a sagger and the saggers placed 5, 8, and 13 high, respectively. A second bung in each sagger was similar ware dipped in the regular glaze. The trial glaze was as follows:

Frit		Mill Batch	
Borax	23.5	Frit	40.25
Whiting	18.5	Flint	10.50
Flint	30.5	Cornwall Stone	28.75
Soda Ash	12.75	White Lead	21.00
China Clay	14.75		
	100.00		100.50

Taking Cornwall Stone as equivalent to:

China Clay	34
Feldspar	31
Quartz	35
	100

the molecular formula of the glaze is:

$$\begin{matrix} 0.340\ Na_2O \\ 0.051\ K_2O \\ 0.346\ CaO \\ 0.262\ PbO \end{matrix} \quad 0.280\ Al_2O_3 \quad \begin{matrix} 2.822\ SiO_2 \\ 0.230\ B_2O_3 \end{matrix}$$

Oxygen ratio 3.44

$SiO_2 : B_2O_3 :: 1 : 0.0815$

Veritas firing rings were placed in each sagger and they measured 19½, 20 and 21, reading from the bottom upwards.

The second bung of plates in each sagger (dipped in the regular glaze) was perfectly straight, as was also the ware throughout the rest of the kiln, but those in the three bungs which had been dipped in the trial glaze were warped to a surprising extent. This glaze had not matured.

[1] Presented at Atlantic City Meeting, Feb., 1924 (Whitewares Division).

Several weeks later, the experiment was repeated under precisely the same conditions, but the glost fire was a little harder. The glaze was consequently better matured though still underfired. The result was that the plates came out much straighter, though still more or less warped.

The warping is manifestly caused by the glaze since that is the only variable. I have tried to explain it to myself by assuming that the body softens slightly in the glost fire, and that when the kiln begins to cool, the glaze solidifies before the body has become entirely rigid, and that during solidification the contraction of the glaze is sufficient to pull the still soft body out of shape.

The smaller degree of warping of the second series of trials might be accounted for on the assumption that as the glaze is nearer maturity it has reacted with the constituents of the body to a greater extent and so reduced the difference in contraction.

This explanation does not seem convincing and was only arrived at by a process of elimination. If it were true, one would expect that the glaze (especially in the first series of trials) would be more or less in a state of tension and hence very liable to craze. This, however, is not so. The glaze on the first series of trials, notwithstanding its immaturity, withstood five chillings from 200°C in water at 15°C on some of the plates, on others it crazed slightly on the foot at the fifth chilling.

In the second series of trials, the glaze though better matured, crazed more easily. Three plates were tested and each crazed on the foot on the second chilling from 200°C to 15°C. This seems inconsistent with the suggested explanation.

As I have failed to find any reference in the literature to such a case of warping, and have been unable to find anyone who has met with it or who can throw any light on the cause, I have brought it before the SOCIETY in the hope that some member may be able to suggest an explanation.

The resistance to crazing of the first series seems remarkable, not only because of the immaturity of the glaze but also because of its high soda content.

SEBRING POTTERY COMPANY
SEBRING, OHIO

NOTE ON THE RATIONAL ANALYSIS OF CLAYS[1]

By G. S. Tilley[2] and J. D. Sullivan[3]

ABSTRACT

Several feldspars, muscovite, biotite and quartz, as well as diaspore clay and kaolinite, in fairly pure state, were severally subjected to the procedure of "rational analysis" of clays. It was shown by analysis of the residues and solutions obtained:

1. That all the feldspars were attacked to a greater or less extent
2. That the micas were attacked more than the kaolinite
3. That kaolinite was not wholly decomposed by the treatment
4. That diaspore clay was not approximately decomposed by the treatment
5. That the amount of decomposition of all the substances depends to a considerable extent on the time and temperature of treatment.

As a result of these conclusions, it would not be possible to draw any conclusion as to the clay substance content of a particular clay from the results of a rational analysis.

As a further result, it would not be possible to draw any conclusion as to the content in feldspars and quartz by further analysis or treatment of the residue from acid treatment, because the feldspars would have already been dissolved out in part before the attempt was made to determine them by this procedure.

The method, whatever its empirical value, cannot be said to show even approximately either clay substance, feldspars, micas, or quartz in any given clay.

In connection with experimental work being carried on by the Bureau of Mines with the object of developing a process for preparing aluminum sulphate from clays, it has been desirable to know the approximate mineralogic composition of the clays used. The methods available were "rational analysis," microscopic examination, and calculation of the so-called "norm" from the chemical composition of the clay as determined by analysis.

On investigating the methods themselves, we found, as Washington says[4] that "there is great divergence of opinion, even among ceramists themselves as to the value of the 'rational' analysis."

It seemed to us that a study of the action of the procedure of the rational analysis on the pure minerals themselves, which occur as a mixture in clay might throw some light on the controversy. We, therefore, obtained in a quite pure state the following minerals:

Orthoclase	Microcline	Muscovite
Albite	Labradorite	Biotite
Oligoclase	Quartz	Kaolinite

All of them were ground to pass 100-mesh, and examined with the microscope by methods of *Bulletin* **679** of the U. S. Geological Survey, and found to have at most very slight admixture with foreign substances.

[1] Published with permission of the Director, U. S. Bureau of Mines.

[2] Associate Chemist, Pacific Expt. Station, Bureau of Mines, Berkeley, California.

[3] Junior Physical Chemist, Pacific Expt. Station.

[4] *Jour. Amer. Ceram. Soc.*, **1**, 406 (1918).

A sample of diaspore containing 80% alumina was also obtained, ground and examined, and treated as were the other nine minerals. All ten were put through the process of rational analysis,[1] as far as determining the alumina dissolved by the acid treatment. Briefly, the method consists in heating the substance with sulphuric acid solution till fumes of sulphuric acid appear. Kaolin is expected to dissolve and micas and feldspars remain insoluble. Hence analysis of the soluble and insoluble portions is supposed to give figures which are functions of the content of the sample in kaolin and the more complex silicates. Our results were so significant that it was considered unnecessary to go on with the determination of the silica and alumina in the undissolved residues.

The results of the determination of iron and alumina in the solutions are tabulated in the following table:

Substance (1 g. each sample)	Analysis of solutions (total amount of each constituent found) Alumina	Ferric oxide	Substance (1 g. each sample)	Analysis of solutions (total amount of each constituent found) Alumina	Ferric oxide
Biotite	0.1260	0.1660	Albite	0.0008	0.0009
	0.1192	0.1025		0.0024	0.0009
Muscovite	0.3433	0.0227	Quartz	0.0002	0.0009
	0.2911	0.0197		0.0004	0.0009
Orthoclase	0.0030	0.0005	Kaolinite	0.1819	0.0179
	0.0004	0.0009		0.1677	0.0203
Microcline	0.0034	0.0018	Diaspore	0.0190	0.0220
	0.0037	0.0028		0.2729	0.0370
Labradorite	0.0843	0.0072	Oligoclase	0.0027	0.0018
	0.0169	0.0063		0.0054	0.0028

In several tests the samples were evaporated to fumes more slowly than the others, with the result that in every case of slow evaporation the amount of alumina in the solution was considerably more than with the others, although both conformed to the directions for the analysis. This effect is most noticeable with diaspore and muscovite, but shows also with kaolinite and biotite. This is in agreement with numerous observations during our work here on the decomposition of clays by sulphuric acid. We found in practically every case in which the acid rapidly came to a condition of high concentration, that the action on the clay minerals was much less than when the acid contained water sufficient to dilute it to at most 70–75% H_2SO_4 for a longer time, other conditions being equal. We ascribed this to the formation of an insoluble protecting layer on the surface of the mineral grains, and found that such an insoluble acid aluminum sulphate did exist. It is easily made, for example, by adding concentrated sulphuric acid to a strong solution of aluminum sulphate, the resulting precipitate not being precipitated out simply by common ion effect, but being

[1] U. S. Bureau of Mines, *Bull.* **53**, 38–41.

a compound of the composition $Al_2(SO_4)_3.H_2SO_4$. Analysis of the insoluble compound obtained by heating clays with sulphuric acid at higher temperatures appears to be more nearly $Al_2(SO_4)_3.2H_2SO_4$, by determination of the ratio of SO_4 to Al_2O_3.

It is very slowly decomposed even by boiling water—cakes of decomposed clay cemented together by this substance often taking two days digestion on the steam bath to break up a cake weighing only 25 grams.

The formation of this insoluble substance under the conditions of the rational analysis, and directions for avoiding it, or dissolving it after formation must be taken into account by any method claiming accuracy.

Washington[1] mentions as factors seriously influencing the results, the concentration of the reagent, the time of treatment, temperature of treatment, and whether this is attained suddenly or gradually, or is uniform or varied during the treatment. These all bear on the formation of this insoluble acid sulphate of alumina whenever the acid becomes concentrated to about 75–80%, with consequent protection of the minerals from further action to greater or less degree.

In other words, it is almost impossible to obtain the same results on the same substance without the most careful regulation of the conditions of attack by sulphuric acid.

Further, a study of the table of results will indicate at a glance the impossibility of calculating "clay substance" from the percentage of alumina in the solution. The feldspars are all attacked to a greater or less amount, and the micas are attacked almost as much as the kaolinite itself. The fact that the feldspars are attacked and go into solution to a certain extent renders the determination of alumina and silica in the undissolved residue as a means of calculating feldspathic constituents worthless, the percentage error in that case being as much greater than in calculating clay substance by dissolved alumina as the clay substance exceeds the feldspathic constituents.

We are, therefore, inclined to agree with Washington[1] in deciding that "the methods of 'rational' analysis can furnish little but approximate and uncertain, and probably more or less erroneous and misleading, information."

The results with diaspore, even on the prolonged digestion resulting in the higher extraction of alumina, show that in the case of high alumina clays or "jehytes" of which diaspore is a type, the method of rational analysis completely fails to give even an approximation to the true content of clay substance.

[1] *Loc. cit.*, p. 408.

THE OXIDATION OF CERAMIC WARES DURING FIRING[1]—II. THE DECOMPOSITION OF VARIOUS COMPOUNDS OF IRON AND SULPHUR UNDER SIMULATED KILN CONDITIONS[2]

By Frederick Gray Jackson[3]

Ferric Sulphate in Clay

So far we have got along without having to go much into balanced actions. The case of ferric sulphate, however, the final product formed in the weathering of iron-sulphur compounds in clays, calls for a consideration of a balanced action. It would seem that, particularly in an atmosphere of pure oxygen, the reaction

$$Fe_2(SO_4)_3 4H_2O = Fe_2O_3 + 3SO_3 + 4H_2O$$

would proceed without hindrance to completion. We must remember, however, that the reaction

$$2SO_2 + O_2 \rightleftarrows 2SO_3$$

is a balanced one, and that hot clay is a good catalyst. The equilibrium point of this reaction changes with changing temperature. With this in mind, it is not so surprising to find, beginning at about 500°, a marked evolution of SO_2. There is also the probability that some of this SO_2

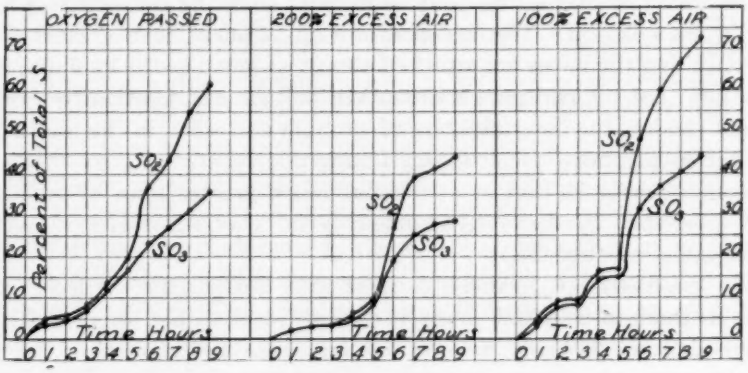


Fig. 7.—Ferric sulphate.

recombines with iron oxide to form an incompletely oxidized compound or iron and sulphur. The possibilities are ferrous sulphate, basic sulphates, sulphites, and possibly hyposulphites. There may be several different compounds formed with various decomposition temperatures. The problem, therefore, becomes more complicated.

[1] Published by permission of the Director of the U. S. Bureau of Mines.

[2] For Part I of this paper see *Jour. Amer. Ceram. Soc.*, **7** [4], 223 (1924).

[3] Associate Chemist, Ceramic Station, U. S. Bur. of Mines, Columbus, Ohio.

A further complication arises when we add CO_2 to the atmosphere. There is then the possibility of forming, not only the above compounds by reaction of iron oxide and water with SO_2, but also oxycarbonates as well as mixed compounds. Iron lends itself well to the formation of complex molecules, the nature of which is particularly difficult to discover. It will be noticed in both experiments where CO_2 is passed over ferric sulphate that there is a slackening of sulphur evolution during the third hour. It is probable that some secondary reaction took place at that time, which changed the whole course of the succeeding action.

When the amount of oxygen is still further reduced, we have a second pause in sulphur evolution during the fifth hour. This is evidence of further complicating actions. During the sixth hour, in all cases, there was a marked increase in evolution both of SO_3 and SO_2, but particularly so in the case under consideration. (See Fig. 7.) To get to the bottom of this subject might require years of experiments.

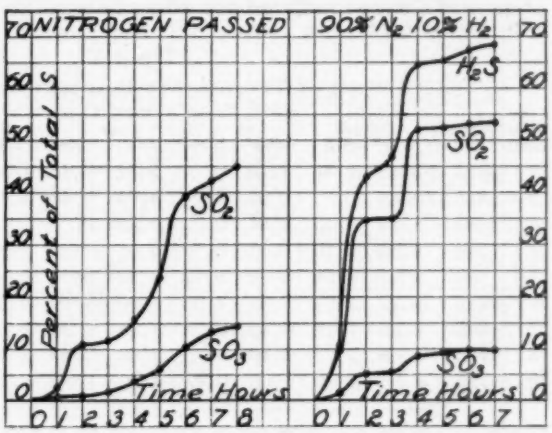


FIG. 8.—Ferric sulphate.

When ferric sulphate in clay is heated in an atmosphere of pure nitrogen, it would seem at first as if the reaction should proceed as

$$Fe_2(SO_4)_3 = Fe_2O_3 + SO_3$$

with no SO_2 formed. However, the reaction

$$2SO_3 \rightleftharpoons 2SO_2 + O_2$$

has an equilibrium point in the presence of a catalyst such as hot clay. The position of this equilibrium point, as well as the time in which it is reached, varies with the temperature. The tendency appears to be the formation of more SO_2 at low than at high temperatures. Since the rate of evolution of SO_3 varies with the temperature, the problem becomes very complicated. It was hoped that, in burns in an atmosphere of pure nitrogen, some calculation of the iron-sulphur-oxygen ratio remaining in the clay after the burn could be made. Since an undeterminable amount

of oxygen was given off as gas in the natural balancing of SO_3 and SO_2, calculation cannot be made from the data in hand.

When hydrogen gas was mixed with nitrogen in the atmosphere, a further complication was introduced. There was probably a considerable reaction around 450° to 480° as follows:

$$SO_3 + H_2 = SO_2 + H_2O$$

$$SO_2 + 3H_2 = H_2S + 2H_2O$$

By thus reducing the concentration of SO_3 in the atmosphere, the evolution of more SO_3 was stimulated according to mass law principles. (See Fig. 8.)

TABLE VI

RESULTS OF TREATMENT OF CLAY WITH FERRIC SULPHATE

Time, hours	Temp., °C	Oxygen		200% Excess air		100% Excess air		Nitrogen		90% Nitrogen 10% Hydrogen		
		SO_3	SO_2	SO_3	SO_2	SO_3	SO_2	SO_3	SO_2	SO_3	SO_2	H_2S
1	425	3.48	0.45	1.72	0	2.81	0.45	0.41	1.71	1.39	8.36	0.18
2	445	1.39	0	0.93	0	4.74	0.42	0.54	8.23	3.69	21.34	8.27
3	480	1.93	0.13	0.37	0	0.29	0[1]	0.53	0	0.12	0	3.55
4	510	4.35	1.10	2.64	0	6.08	0.83	2.39	1.93	3.40	13.72	0.67
5	560	4.93	1.58	2.59	0.42	0.28	0[1]	2.21	5.87	0.42	0	0.40
6	615	6.72	5.61	10.43	7.55	16.60	16.16	4.20	11.09	0.82	0	1.22
7	665	3.92	7.18	6.42	6.13	5.88	6.29	3.02	0	0	0	0.87
8	720	3.68	7.72	2.40	0	2.82	3.40	1.26	1.68	0	0	5.68
9	775	5.05	2.00	1.00	0.97	4.50	1.90	....[2]	....	....	....	....
Totals		35.45	25.77	28.50	15.07	43.80	29.45	14.56	30.51	9.84	43.42	20.82
Total per cent sulphur evolved		61.22		43.57		73.25		45.07		74.08		

[1] No CO_2 caught.

[2] 775° attained in 8 hours.

Ferric Sulphate and Coal

When powdered coal was mixed in equal weight with the ferric sulphate added to clay, and the clay burned in pure oxygen, the result was surprisingly simple. The coal all burned out during the first two hours to CO_2, and either contributed a little SO_2 itself or decomposed a very little ferric sulphate. After that, conditions were the same as in the experiment without coal.

When CO_2 was also passed, however, the situation was very different. The coal then burned more slowly to form CO in the presence of the CO_2, and, failing, a ready supply of oxygen attacked and decomposed the ferric sulphate to form SO_2. A possible reaction would be:

$$Fe_2(SO_4)_3 + 3C = Fe_2O_3 + 3CO + 3SO_2$$

or

$$Fe_2(SO_4)_3 + 3CO = Fe_2O_3 + 3CO_2 + 3SO_2$$

Consequently, over 30% of the sulphur was given off as SO_2 in the second hour. The evolution of SO_3 was also a little greater than before in the second hour, due to some of the SO_2 oxidizing to restore the proper balance and to the extra heat generated by the burning coal. During the last three hours the evolution of sulphur appears to be less than before. This decrease, however, is only relative to the amount of sulphur remaining in solid form.

When the oxygen supply is further decreased, much the same sort of action takes place, but more slowly and more nearly completely. The burning of the carbon is spread over the second and third hours, and

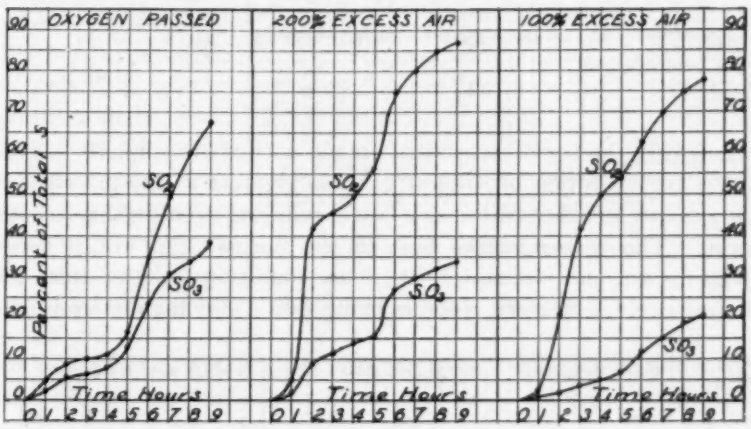


FIG. 9.—Ferric sulphate and coal.

37.78% of SO_2 is liberated during this period. It has already been shown that it would take three hours to supply enough oxygen to burn this amount of coal, so it would be expected that the reaction would proceed more slowly and with a greater proportion of SO_2 formed, as is found. The decrease in SO_3 evolution would also be explained by the law of mass action. When there is a deficiency on one side of a balanced action the action tends to make up that deficiency. In the reaction

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

if there is less oxygen present there will be a tendency for the reaction to run to the left and make more oxygen.

The greatest amount of SO_3 evolved is in the sixth hour in all of these three experiments, as it was in the similar three without coal. This would indicate that there was no very radical difference in them. (See Fig. 9.)

TABLE VII

RESULTS OF TREATMENT OF CLAY WITH FERRIC SULPHATE AND COAL

Time, hours	Temp., °C	Oxygen SO_3	Oxygen SO_2	200% Excess air SO_3	200% Excess air SO_2	100% Excess air SO_3	100% Excess air SO_2
1	425	2.24	1.84	1.83	2.42	0.62	0.77
2	445	3.40	1.39	6.78	30.38	1.16	18.12
3	480	0.82	0	3.68	1.50	1.34	19.66
4	510	1.28	0	2.51	6.90	1.65	6.55
5	560	4.90	0	2.41	0.50	2.03	2.08
6	615	10.53	7.91	1.69	6.80	4.87	3.92
7	665	7.27	7.06	2.88	2.77	3.53	3.15
8	720	3.10	7.70	2.27	2.48	3.80	1.90
9	775	4.50	3.40	1.80	0	1.78	1.05
Totals		38.04	29.30	38.85	53.75	20.78	57.20
Total per cent sulphur evolved		67.34		92.60		77.98	

In reviewing the eight experiments made with ferric sulphate it is evident that the evolution of sulphur gases is greatest in the presence of a reducing agent, and that carbon is a better reducing agent in this case than hydrogen. The carbon works best in the normal kiln atmosphere of 100% excess air, and fortunately these are conditions easy of attainment in kiln practice. Therefore, when working with a clay high in ferric oxide,

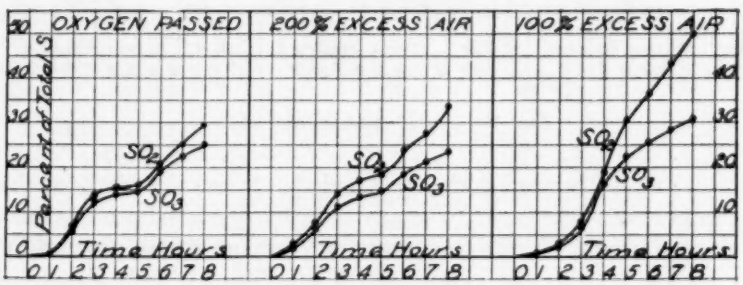


FIG. 10.—Ferrous sulphate.

and containing enough sulphur to make trouble, or when using a high sulphur coal, a little fine coal mixed in the clay will make the sulphur burn off more nearly completely and at a lower temperature.

It will be shown in a subsequent paper of this series that iron oxide in the ware and sulphur from the coal react to form ferric sulphate. A kiln must be held at comparatively low temperature until this sulphur is burned out. These experiments show that addition of a little coal to the ware and an increased oxygen supply should shorten this time of sulphur elimination.

Ferrous Sulphate

Ferrous sulphate was included in this study, not because it was thought that it could exist native in clay, but because it may well be formed as an intermediate product in the decomposition of natural compounds.

Eight burning conditions were studied. It is evident that oxygen is not helpful to the decomposition of the salt and evolution of sulphur. Under identical thermal conditions, with 100% oxygen the yield was 29% of the sulphur added; with 18% oxygen the yield was 33.7%; with 10% oxygen the yield was 50%; with nitrogen alone the yield was 67.6%; and with nitrogen and 10% hydrogen the yield was 53%. (See Figs. 10 and 11.)

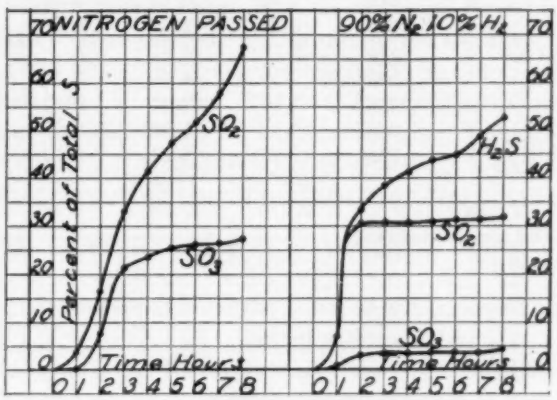


FIG. 11.—Ferrous sulphate.

When lampblack was mixed with the ferrous sulphate in the clay, and burned in pure oxygen, the local heating due to the rapid combustion of the lampblack in the oxygen raised the temperature rapidly, and caused a large evolution of sulphur in the first two hours. After the lampblack had burned out, the evolution of sulphur was slow. With 200% excess air (18% oxygen), the combustion of lampblack would be slower, the local

TABLE VIII

RESULTS OF TREATMENT OF CLAY AND FERROUS SULPHATE

Time, hours	Temp., °C	Oxygen		200% Excess air		100% Excess air	
		SO_3	SO_2	SO_3	SO_2	SO_3	SO_2
1	425	0.27	0	2.25	0.24	0.92	0
2	445	5.39	1.11	3.82	0.72	1.57	0
3	480	6.38	0.18	4.99	2.39	4.40	0.77
4	510	1.93	0	2.50	0	9.64	1.72
5	560	0.65	0	1.26	0	5.86	5.26
6	615	4.45	0	3.83	1.20	2.83	3.60
7	665	3.59	1.33	2.33	0.70	3.20	3.59
8	775	2.71	1.06	2.50	3.85	2.85	3.94
Totals		25.37	3.68	23.58	10.10	31.27	18.88
Total per cent sulphur evolved		29.05		33.68		50.15	

TABLE IX

RESULTS OF TREATMENT OF CLAY AND FERROUS SULPHATE

Time, hours	Temp., °C	Nitrogen		90% Nitrogen 10% Hydrogen		
		SO_3	SO_2	SO_3	SO_2	H_2S
1	425	0	3.69	0.69	6.22	0
2	445	7.62	5.22	2.28	21.44	2.87
3	480	13.77	2.32	0.26	0	4.83
4	510	2.56	6.41	0	0	2.63
5	560	1.61	4.50	0.14	0	2.25
6	615	1.07	3.16	0	0	1.25
7	665	0	5.98	0	0	3.87
8	775	1.07	8.61	0.77	0	4.18
Totals		27.70	39.89	4.14	27.66	21.88
Total per cent sulphur evolved			67.59		53.68	

heating less, and so much oxygen was present that the yield was held down to 43% of the total sulphur.

When 100% excess air was passed (10% oxygen), the lampblack reduced much of the salt, by the reaction,

$$FeSO_4 + C = FeO + CO + SO_2$$

or some similar action, since there was not enough oxygen in the atmosphere to burn the lampblack as fast as it was available. The yield was high, due to the smelting action and the low oxygen content of the atmosphere. (See Fig. 12.)

TABLE X

RESULTS OF TREATMENT OF CLAY AND FERROUS SULPHATE AND LAMPBLACK

Time, hours	Temp., °C	Oxygen		200% Excess air		100% Excess air	
		SO_3	SO_2	SO_3	SO_2	SO_3	SO_2
1	425	3.60	12.67	1.19	8.42	0.54	5.34
2	445	5.02	30.14	3.63	13.88	1.72	48.76
3	480	0.76	0.21	1.30	1.67	1.19	2.10
4	510	0.68	0.33	0.38	0.73	2.75	1.80
5	560	0.96	0.38	0.89	0	0.42	1.00
6	615	1.76	0.49	1.80	0.61	1.65	0.20
7	665	1.90	1.08	1.60	0.67	1.73	1.10
8	775	0.85	1.00	2.18	3.79	0.95	2.10
Totals		15.53	46.50	12.97	29.77	10.95	62.40
Total per cent sulphur evolved			62.03		42.74		73.35

When ferrous sulphate is burned in pure nitrogen a very interesting study is before us. Unlike the case of ferric sulphate, we have an incompletely oxidized system. Therefore, when there is a tendency for SO_3 to break up into SO_2 and O, the ferrous iron will take up the oxygen

instead of its passing off as gas. The normal reaction would be expected to be:

$$2FeSO_4 = Fe_2O_3 + SO_2 + SO_3$$

Hence there is therefore no tendency to form free oxygen.

In a preliminary experiment it was found that, as might be expected, on drying the clay bar, the ferrous sulphate was drawn to the surface and that it there oxidized in the air. This oxygen thus taken up interfered with any calculations that could be made. The final form of the experiment consisted in enclosing the clay bar in the combustion tube as quickly as possible after it was molded. Nitrogen was passed slowly for a day to "air-dry" the bar. The tube was then heated to about 125°C for another

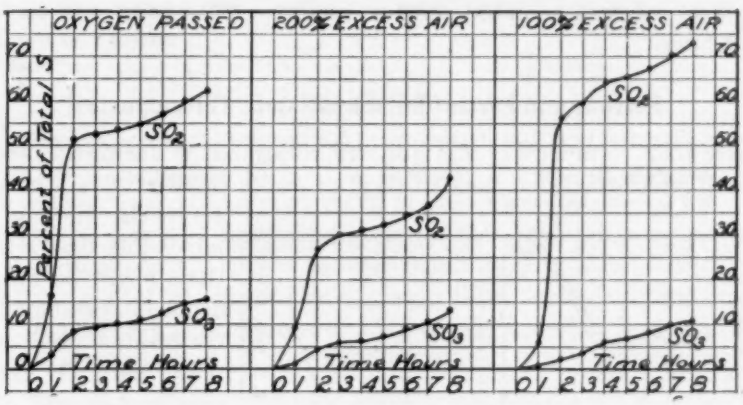


FIG. 12.—Ferrous sulphate and lampblack.

day and night with nitrogen passing. In this way oxidation of the ferrous sulphate was prevented. It was then heated in the regular manner with the results as shown.

From these results we can calculate the reactions that took place. There was put into the bar 0.3659 gram of iron, 0.2090 gram of sulphur, and 0.4181 gram of oxygen in combination. According to the above reaction, if it ran to completion, there would be 0.1045 gram of sulphur and an equal amount of oxygen combined, and 0.2090 gram of SO_2 evolved; 0.1045 gram of sulphur and 0.1568 gram of oxygen would combine to form 0.2613 gram of SO_3, and the 0.3659 gram of iron would combine with the remaining 0.1568 gram of oxygen as Fe_2O_3. However, the reaction was not completed.

In the actual experiment there was 0.1668 gram of SO_2 formed from 0.0834 gram each of sulphur and oxygen. There was 0.1448 gram of SO_3 formed from 0.0579 gram of sulphur and 0.0869 gram of oxygen. There was therefore left in the clay 0.0677 gram of sulphur and 0.0910

gram of oxygen in addition to the Fe_2O_3. The following statement will help clarify this point:

Theoretical Complete Decomposition	Fe, gram	S, gram	O_3, gram	Actual Partial Decomposition	Fe, gram	S, gram	O_3, gram
Put into bar	0.3659	0.2090	0.4181	Put into bar	0.3659	0.2090	0.4181
Evolved as SO_2	..	0.1045	0.1045	Evolved as SO_2	..	0.0834	0.0834
Evolved as SO_3	..	0.1045	0.1568	Evolved as SO_3	..	0.0579	0.0869
Left as Fe_2O_3	0.3659	..	0.1568	Left as Fe_2O_3	0.3659	..	0.1568
Undecomposed	0	0	0	Undecomposed	..	0.0677	0.0910

"Undecomposed" is perhaps not quite the right term, for this sulphur and oxygen no longer exists as ferrous sulphate. A test of the burned bar shows no water-soluble sulphur present. This point will be discussed later.

Ferrous and Ferric "Sulphites" and "Thiosulphates"

These four "compounds" are not well recognized in chemistry, and it was well understood that none of them probably could exist in a natural clay; but it was not impossible that one of them might be formed as an intermediate decomposition product of some naturally occurring iron-sulphur compound. A study of results already obtained indicated that some intermediate sulphur compound was being formed in varying amount under different conditions, and was being "fixed" in the clay. It was with the hope of identifying this compound that the decomposition of every possible combination of iron with sulphur and oxygen was studied in an atmosphere of nitrogen.

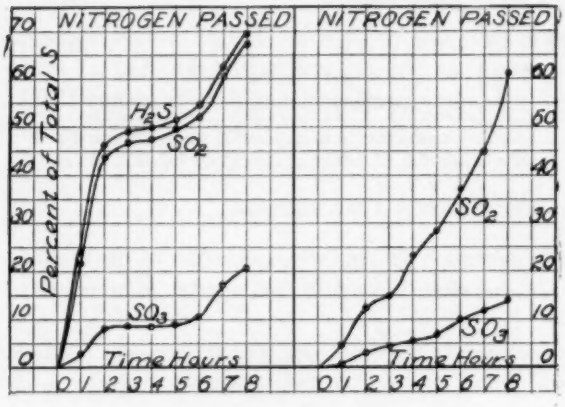


Fig. 13.—Ferrous and ferric "sulphites."

The compounds were given an opportunity to form in the experiments by combining in a clay bar the proper weights of either ferric oxide or siderite, ferrous carbonate, with sodium sulphite or sodium thiosulphate. A study of the evolution of sulphur gases brought out the extent to which the combination had been effected. (See Fig. 13.)

TABLE XI

RESULTS OF TREATMENT OF CLAY AND FERRIC OXIDE OR FERROUS CARBONATE WITH SODIUM SULPHITE

Time, hours	Temp., °C	$Fe_2O_3 + Na_2SO_3$ Nitrogen SO_3	$Fe_2O_3 + Na_2SO_3$ Nitrogen SO_2	$Fe_2O_3 + Na_2SO_3$ Nitrogen H_2S	$FeCO_3 + Na_2SO_3$ Nitrogen SO_3	$FeCO_3 + Na_2SO_3$ Nitrogen SO_2	$FeCO_3 + Na_2SO_3$ Nitrogen H_2S
1	425	0.51	4.33	0	2.78	18.70	2.07
2	445	2.57	4.75	0	5.13	17.20	0.10
3	480	1.40	1.35	0	0.36	2.70	0
4	510	1.04	7.51	0	0.37	0.40	0
5	560	1.09	3.91	0	0.20	1.35	0
6	615	3.34	5.45	0	0.88	1.91	0
7	665	1.38	6.21	0	7.20	1.22	0
8	775	2.60	14.40	0	3.61	13.17	0
Totals		13.93	47.55	0	20.53	56.65	2.17
Total per cent sulphur evolved			61.48			79.35	

Sulphites in Nitrogen

As these experiments were at first conducted, H_2S was not expected nor tested for. It appeared difficult to interpret the results obtained, since more oxygen was evolved than could be reasonably accounted for. The experiments were then repeated, testing for H_2S. With ferrous carbonate and sodium sulphite, 2.17% of H_2S was found, 56.65% of SO_2, and 20.53% of SO_3, a total of 79.35% of the sulphur. With ferric oxide and sodium sulphite, no H_2S was found, and 13.93% of SO_3 and 47.55% of SO_2. The expected reactions were:

$$6FeCO_3 + 6Na_2SO_3 + H_2O = 3Fe_2O_3 + 6Na_2CO_3 + H_2S + 5SO_2$$

and

$$Fe_2O_3 + Na_2SO_3 = Fe_2O_3 + Na_2O + SO_2$$

Any SO_3 that was formed could only be accompanied by an equal amount of H_2S. It would, however, be possible for the SO_3 thus formed to be temporarily held back. It did not seem possible that SO_2 could reduce either Fe_2O_3 or CO_2. Accordingly, another source of oxygen must be sought, and this was found in the drying of the clay bars. In a current of air at 110°C, Na_2SO_3 will take up oxygen, the amount depending upon the degree of wetness of the clay when put into the drier. This would account for the inability to check results.

It was evident, due to the decomposition of sodium sulphite at low temperature, that no iron compound was formed. It was therefore considered not worth while to carry the investigation of these compounds any further.

Thiosulphates

From the two bars to which sodium thiosulphate was added, all of the sulphur was burned off. The total sulphur evolved amounted to 99.71%

of the amount added in the case of ferric iron and 100.12% in the case of ferrous iron. (See Fig. 14.) These deviations from the theoretical are within the limit of accuracy of the experiment, and this makes it comparatively simple to study the mechanism of the reactions. We can divide sodium thiosulphate into parts as follows: Na_2O, not affected by heating; S_2O_2 decomposed and evolved as gases; and H_2O (water of constitution of clay), decomposed. The Na_2O we need not consider. In the case of ferric thiosulphate there was present 0.3186 gram of sulphur combined with 0.1593 gram of oxygen; 0.1137 gram of sulphur was evolved as H_2S with the decomposition of water, the sulphur combined with 0.0071 gram of hydrogen, by decomposition of water, thus liberating 0.0563 gram of oxygen. Adding this to the oxygen already combined with sulphur makes 0.2156 gram of oxygen available; 0.1812 gram of sulphur combined with an equal weight of oxygen to form SO_2; 0.0226 gram of sulphur combined with 0.0340 gram of oxygen to form SO_3. The sum of the two weights of oxygen 0.1812 + 0.0340 = 0.2152 gram. This figure checks with the amount of available oxygen given above 0.2156 gram. The agreement of these two figures is even closer than might be anticipated. This may be tabulated as follows:

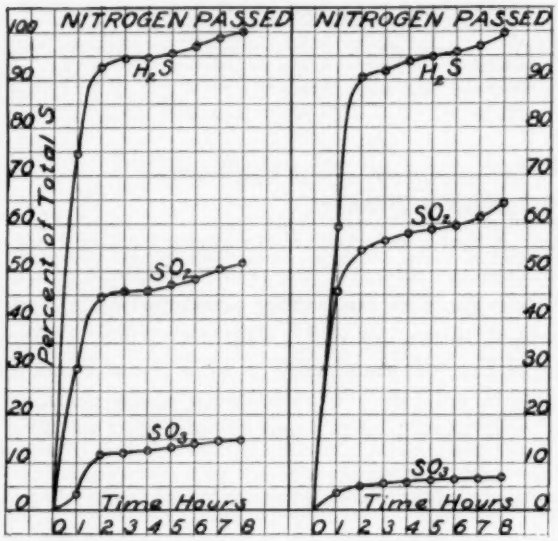


FIG. 14.—Ferrous and ferric "thiosulphates."

	Sulphur available, gram	Sulphur evolved, gram	Oxygen available, gram	Oxygen evolved, gram
Put into clay	0.3186	..	0.1593	..
As H_2S	..	0.1137	0.0563	..
As SO_2	..	0.1812	..	0.1812
As SO_3	..	0.0226	..	0.0340
Totals	0.3186	0.3175	0.2156	0.2152

The calculation shows that the Fe_2O_3, a potential source of oxygen, was not drawn upon at all. Sulphur at 400° to 450°C will decompose water rather than deoxidize Fe_2O_3 in the least degree.

In the case of "ferrous thiosulphate" an even more striking conclusion is reached. Here $FeCO_3$ and $Na_2S_2O_3 + H_2O$ were combined and heated. We can disregard CO_2 and Na_2O as not entering into the rest of the reaction. There was present 0.2440 gram of Fe combined with 0.0698 gram of oxygen and 0.2787 gram of sulphur combined with 0.1394 gram of oxygen. Of this sulphur, 0.1351 gram formed H_2S, combining with 0.0084 gram of hydrogen from water, thus liberating 0.0675 gram of oxygen. This makes a total of 0.2767 gram of oxygen available; 0.1025 gram of sulphur combined with an equal weight of oxygen to form SO_2; 0.0414 gram of sulphur combined with 0.0621 gram of oxygen to form SO_3. This accounts for 0.1646 gram of oxygen. To convert the 0.0423 gram of FeO to Fe_2O_3 requires 0.0349 gram of oxygen. This accounts for 0.2693 gram of oxygen as against 0.2767 gram calculated as available, a good check. This is summarized as follows:

	Iron	Sulphur available, gram	Sulphur evolved, gram	Oxygen available, gram	Oxygen evolved, gram
Put into clay as FeO	0.2440	..	..	0.0698	..
Put into clay as S_2O_2	..	0.2787	..	0.1394	..
Evolved as H_2S	..	..	0.1351	0.0675	..
Evolved as SO_2	..	..	0.1025	..	0.1025
Evolved as SO_3	..	..	0.0414	..	0.0621
To form Fe_2O_3	..	..	..	..	0.1047
Totals	0.2440	0.2787	0.2790	0.2767	0.2693

The close agreement of these two last figures brings out the fact that between 400° and 450°, when a ferrous salt, sulphur, and water are present, the oxidation of ferrous to ferric oxide will go to completion, even though water is decomposed and H_2S is formed. (See Fig. 14.)

TABLE XII

RESULTS OF TREATMENT OF CLAY AND SODIUM THIOSULPHATE AND FERRIC OXIDE OR FERROUS CARBONATE

Time, hours	Temp., °C	$Fe_2O_3 + 3Na_2S_2O_3$ Nitrogen SO_2	SO_2	H_2S	$FeCO_3 + Na_2S_2O_3$ Nitrogen SO_2	SO_2	H_2S
1	425	3.87	41.73	14.00	2.98	26.68	44.45
2	445	1.15	7.77	21.70	8.53	5.97	4.05
3	480	0.38	1.30	0	0.34	1.15	0
4	510	0.58	1.15	0	0.23	0	0
5	560	0.32	0.40	0	0.92	0.42	0
6	615	0	0.95	0	0.43	0.58	0
7	665	0.33	1.10	0	0.89	1.20	0
8	775	0.48	2.50	0	0.55	0.75	0
Totals		7.11	56.90	35.70	14.87	36.75	48.50
Total per cent sulphur evolved		99.71			100.12		

Residual Sulphur

One of the most striking features of this series of results is that, in many cases, far from the entire amount of sulphur is evolved at a temperature of 775°C. It is evident that holding at this temperature indefinitely would not liberate the remaining sulphur. This was shown by the experiments in the first paper of this series. The amount of this residual sulphur varies both with different compounds and with different atmospheres. The question naturally arises: Why is this sulphur not evolved and in what form does it exist?

It is felt that a complete answer to this question will be of the utmost value to the ceramic industries. There are two principal factors which retard the operation of an industrial kiln—namely, the evolution of water, and the oxidation of sulphur. Until these two processes are completed the temperature of the kiln may not be advanced beyond certain points without damage to the ware. Many superintendents have worked by rule of thumb, by repeated trial and observation, until they have developed as rapid a heating schedule as they dare use. It may well be, however, that a scientific knowledge of the chemical reactions involved will allow them to shorten their schedule in some way or enable them to produce a superior product. By this means the manufacturer would produce more ware with the same equipment, reducing overhead expense; he would use less coal per unit of ware, promoting conservation; and he would be able to produce at a lower cost, pleasing the public and increasing the demand for ceramic wares.

The question cannot be answered in a few words, nor can the solution be discovered by a few experiments. Its study was begun by selecting some of the burned clay bars which had given the lowest yields of sulphur, breaking out a section in the center, grinding this fine, and weighing out a 10-gram sample of each bar. These samples were then extracted with 500 cc. of boiling water each for half an hour. The water was then decanted and filtered until perfectly clear, then tested for sulphate. The residue was then extracted once more with dilute aqua regia, and the filtered extract tested for sulphate. In neither case, from any of the bars, was as much as 1 per cent of the sulphur originally put into the bar thus extracted.

The conclusion must be drawn that something strange has happened. All of the familiar compounds of iron and sulphur are apparently either soluble in water, such as those containing oxygen, or at least are soluble in boiling dilute aqua regia, such as sulphide, pyrite, etc.

A third extraction was then tried, using a mixture of dilute nitric and hydrofluoric acids in a platinum dish, and evaporating on a steam bath. The nitric acid was added to oxidize any SO_2 which might be liberated, or otherwise evolved, to H_2SO_4. This would not be vaporized at this

temperature. The technique of this process of extraction has not as yet been developed to give complete satisfaction. Quantitative results, therefore, can not be given here. Preliminary work, however, points to at least a large proportion of the residual sulphur being rendered soluble in water by this treatment. A plausible explanation concerning this sulphur is as follows.

When any compound of iron and sulphur, with or without oxygen, starts to decompose with heat, it is momentarily in an unstable condition. To use terms of plain, old-fashioned chemistry, some of its bonds of attraction are temporarily unsatisfied. They will satisfy themselves by combining with whatever is present that best suits them under the existing condition. It happens that at just about this temperature the kaolinite molecule is profoundly disturbed by splitting off of water. It may well happen that a combination may form between a partly oxidized iron-sulphur compound or radical, and silica. (Justification for the suggestion that such a compound may be formed is found in the ease with which both silica and iron enter into the formation of complex molecules.) An idea of the difficulty of determining the composition of such a complex compound can be had by a survey of the number of complex silicates. It may well happen that a series of such compounds is formed.

The first clue is the fact that compounds of ferrous iron and silica are, in general, easily fusible. This would indicate that the compound carried ferrous rather than ferric iron. This suspicion is strengthened by the low yield of sulphur evolved when ferrous sulphate was heated in oxygen. This would indicate that $FeSO_4$ was close to the composition of the combining radical. The unoxidized ferrous compounds—sulphide and pyrite—yielded the least sulphur as gases when conditions were only slightly oxidizing. This would seem to indicate that the radical was an incompletely saturated one. When ferrous sulphate was heated in nitrogen, an excess of SO_3 over SO_2 was given off during the first three hours. This might indicate the formation of some compound that is lower in oxygen content than $FeSO_4$. For example: $FeSO_3$ might be formed and be disappearing from the sphere of reaction as a complex with a silicate. Above 500°C the tendency is the other way, and SO_2 comes off in excess. It is possible that the iron compound forming the complex is wanting to oxidize and is reducing SO_3 to SO_2. If so, this oxidation has progressed beyond the ratio of $FeSO_4$, for residual sulphur and oxygen are in the ratio of a mixture having about the proportions $6FeSO_4$, $Fe_2(SO_4)_3$. The general term of "ferrous sulpho-silicate" may be tentatively applied to this complex.

All of this is, so far, little more than speculation. However, results so far prove:

1. That the reactions for the evolution of sulphur from an iron-sulphur compound in clay are generally complex.

2. That not all of the sulphur is given off as gas at temperatures at which the well known iron-sulphur compounds decompose.

3. That the amount of sulphur that is not evolved varies for different compounds and for the same compound in different atmospheres.

4. That the sulphur remaining in the burned clay is in the form of a compound insoluble in water or in dilute aqua regia, as were the compounds in which the sulphur was introduced.

Application to Industry

How does ferrous sulpho-silicate interest the ceramic manufacturer? It may be of vital interest to many. When sulphur gets bound up in a silicate molecule it is not easily decomposed by heat. A temperature is eventually reached, however, when the compound is decomposed, perhaps rather suddenly. If, at this temperature, the ware is approaching vitrification and has a low porosity, and if the volume of sulphur gases is considerable, the gas may not be able to get out as fast as it is formed. Under such conditions a gas pressure develops inside the viscous ware, and consequently the ware swells. Oxygen cannot penetrate against this current of gas, consequently the iron remains in the ferrous state, at least in part, and forms black ferrous silicate. This is the familiar "black core."

It is to avoid the production of bloated and cored ware that the ceramic manufacturer must heat his kilns slowly. The more we know about ferrous sulpho-silicate the better we will know how to prevent the formation of unsalable products. In a subsequent paper the formation of this compound will be discussed from a different point of view.

U. S. Bureau of Mines
Lord Hall, Ohio State University
Columbus, Ohio

THE DEAD BURNING OF DOLOMITE—V[1]

By James Thomas Robson and James R. Withrow

Burn No. 5

The material calcined in Burn 4 was broken in the jaw crusher and run through the disc pulverizer, being ground to the following degree of fineness:

Mesh	Per cent residue
20	None
40	13
80	30
100	27
150	8
Fines	22

The feasibility of various bonds for use of the calcined material was tried in this burn. The burning curve of Burn 4 was followed throughout except that the temperature was taken to cone 18 down rather than cone 17 down as in Burn 4. This was done in order to bring an even heat throughout the kiln. At cone 17 down, one side was hotter than the other, which had cone 17 deformed to about 2 o'clock.

The methods of preparation of bricks for this burn, together with their drying and burning results, follow. All linear shrinkages given are on the original length basis.

Starch Paste as a Bond

A very thick starch paste was made by adding a slip of starch in cold water to boiling water and thoroughly stirring.

Bricks SA14 and S1A14.—These bricks were made of calcined A14 composition to which was added just enough of the starch paste to make it possible to be molded. Brick SA14 was tamped into the mold by hand. Brickette S1A14 was not a standard size brick as was SA14 but simply a one-inch bar about six inches long molded by hand. These bricks formed very well in the molds, but cracked badly upon drying so that they were not burned.

Brick SA14C.—This brick was made of 2,300 grams calcined A14C composition, using 650 grams of starch paste as a binder, and pressed into a standard size brick at 480 pounds per square inch pressure. It pressed and formed very well, but upon drying cracked badly throughout.

It thus appears to be impossible to use starch paste as a bond for calcined A14 composition because of cracking upon drying.

[1] Published by permission of the Director, U. S. Bureau of Mines. See "The Dead Burning of Dolomite," *Jour. Amer. Ceram. Soc.*, **7** [1], 61; [2], 141; [3], 207; and [4], 300 (1924).

Magnesium Chloride Solution as a Bond

Brick MA14.—Made of calcined A14 composition using a saturated solution of $MgCl_2$ as a tempering medium, enough solution being added to make the mixture soft and plastic so that the brick was made by the soft-mud process. It dried without cracking and burned very well except for a few cracks on the bottom. (See Fig. 38.) The linear expansion from plastic to burned was 1.25%.

Brick M1A14.—To 2,000 grams of A14 calcine were added 400 cc. of a 23% $MgCl_2$ solution. This brick was pressed with 460 pounds per square inch pressure. It cracked badly on drying, was rescreened, and, after adding a large excess of the $MgCl_2$ solution it was formed by the soft-mud process. This trial did not crack on drying, but cracked very badly during burning.

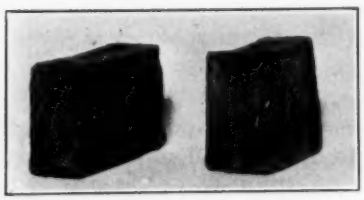


FIG. 38.—Bricks NaD_9 and MA_{14}.

Brick M2A14.—Made by using calcined A14 composition plus 23% of $MgCl_2$ solution and soft-mud process. This brick cracked on drying and was not burned.

It appears necessary to use a saturated solution of $MgCl_2$ as a tempering medium, otherwise if a dilute solution is used, the bricks crack on drying.

Caustic Magnesia as a Bond

Caustic magnesia of the California variety, made for use in stucco work, was used.

Brick EA14.—This brick consists of calcined A14 composition, 90% by weight plus 10% of caustic magnesia by weight. These were thoroughly mixed and screened. Then sufficient water was added to mold it by the soft-mud process. This brick cracked badly on drying. No bonding effect whatever seemed to be exercised by the caustic magnesia present, so that this method was discarded and the brick not burned.

Sorrel Cement as a Bond

An attempt was made to produce Sorrel cement in the calcined dolomite and thus insure a firm bond. This was attempted by using caustic magnesia and $MgCl_2$ solution as shown below.

Brick M3A14.—Made by using calcined A14 mixture weighing 1,000 grams, 300 grams of a 14° Bé. $MgCl_2$ solution and 50 grams of caustic magnesia. This mixture was thoroughly tempered by hand and molded by tamping the mixture in the mold. The brick formed well but cracked badly on drying and was not burned.

The reason for cracking was probably due to the presence of sufficient

free lime in the calcine to cause the Sorrel cement to disintegrate, as explained by Bole and Shaw.[1] These men state that free lime even in amounts under 2% is detrimental to the life of an oxychloride cement and in quantities over 3% causes early disintegration.

Sodium Silicate as a Bond

A solution containing 25% of dry sodium silicate by weight was mixed further with water so that the resulting solution contained 4.5% dry sodium silicate by weight.

Brick NaA14.—Made of calcined A14 composition tempered with sufficient sodium silicate solution so that the resulting percentage of dry sodium silicate on the A14 calcine weight basis amounted to 0.62%. This brick was molded by hand. It cracked badly on drying and was not burned.

Brick NaD9.—Made of D9 composition using sufficient solution to give 0.80% dry sodium silicate. This brick was molded by hand and dried and burned very well. (See Fig. 38.) The brick expanded 1.25% from plastic to burned.

It appears that D9 composition may not be susceptible to this action of cracking during the drying process as is A14 composition.

Gum Arabic as a Bond

Brick FA14.—A thick emulsion of gum arabic was formed by warming an excess of the gum with water. This was cooled and when added to calcined A14 material, it formed small, hard lumps immediately, which made the mass impossible to mold. This material was then heated until it became soft and was then molded by hand. This brick cracked badly immediately upon cooling and was not burned.

Molasses as a Bond

The heavy "second molasses" obtained from cane sugar was used as a bond.

Brick BA14.—This brick was made using 300 grams of molasses to 1,300 grams of A14 calcine. After thorough mixing, a brick was hand molded, which dried and burned very well. (See Fig. 39.) The linear expansion amounted to 1.25%.

Brick B1A14.—Made of A14 material using 450 grams of molasses to 2,000 grams of A14 calcine. This molasses was thoroughly mixed throughout and the mixture then pressed at 550 pounds per square inch. The brick formed was very firm and solid. No cracking occurred upon drying

[1] "Caustic Calcination of Dolomite and its Use in Sorrel Cements," *Jour. Amer. Ceram. Soc.*, **5** [11], 816 (1922).

at 50°C. It burned very well, but shrunk slightly less on the edge in contact with the magnesite brick support. (See Fig. 39.) The linear shrinkage was 9.3%.

Brick B2A14.—This brick was formed of A14 calcine plus molasses and a volume of water equal to that of the molasses. When the water was added to this mixture, it immediately formed small hard lumps. After breaking up the lumps and thoroughly tempering, a brick was tamped in the mold by hand. This brick swelled to a much larger size upon drying and completely disintegrated when an attempt was made to remove it from the mold.

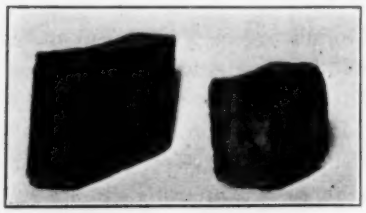


FIG. 39.—Bricks BA_{14} and B_1A_{14}.

Bricks B3A14, B4A14, and B5A14.—Those bricks which cracked on drying namely: SA14, S1A14, SA14C, M2A14, M3A14, EA14, NaA14, FA14, and B2A14 were again ground through the rolls and made into bricks using molasses as a bond. These bricks were made using 515 pounds per square inch pressure. They did not crack upon drying, but cracked during the burning process. This cracking was probably due to the fact that the previous bonds containing much water were not driven out before adding the molasses and although no cracks were noticed upon drying after adding molasses, nevertheless the water was still present and strains may have been set up both in the drying and burning process. These bricks were dried over night at 50°F.

FIG. 40.—Bricks DD_6 and R_6A_{14}.

Dextrin as a Bond

Brick DD6.—Made of 1,500 grams of calcined D6 composition, using 50 grams of thick dextrin paste formed by mixing equal parts of corn dextrin and flour in boiling water until a thick paste was formed. The 50 grams of paste was mixed with 150 cc. of water and after mixing throughout the D6 calcine by hand, was pressed into a brick using 480 pounds per square inch pressure. This brick formed, dried, and burned very well. (See Fig. 40.) Its linear shrinkage was 11.4%.

Raw Material for Calcine

Bricks R6A14 and R7A14.—These bricks were made of composition A14 using raw dolomite (100-mesh) plus C.P. fluxes and mixed with sufficient water to make a very thick slip. They were formed in a standard

size wooden mold. These bricks dried in very good condition. R6A14 burned well, similar to brick R3A14 in Burn 3. (See Fig. 40.) It had 28.0 % linear shrinkage. R7A14 fell over against a silica brick and fluxed with it.

Bricks R1A14C and R2A14C.—These were made of raw 100-mesh dolomite plus the commercial fluxes including North Carolina kaolin similar to composition A14C.[1] R1A14C was molded by the soft-mud process. It dried and burned well except for a small crack clear through the brick. (See Fig. 41.) Brick R2A14C was pressed, using 498 pounds per square inch pressure. It dried very well, but developed three large cracks on burning. The linear shrinkage for R1A14C was 25.7%. The linear shrinkage for R2A14C amounted to 25.7% also.

FIG. 41.—Bricks $R_1A_{14}C$ and $RA_{14}G$.

Bricks RD6 and R1D6.—These bricks were made of raw D6 composition. RD6 was pressed at 535 pounds per square inch pressure and R1D6 was hand molded. Both dried well, but cracked rather badly on burning, especially R1D6.

Brick X15A14.—Made of composition similar to bricks X13A14 and X14A14 as given earlier in this paper.[2] This brick dried well, but cracked badly and was glossy due to overfiring at cone 18.

Use of Gouverneur Dolomite

In order to determine whether or not other forms of magnesite could be dead burned the same as that from Cedarville, a batch of A14 composition was made using C.P. fluxes and a metamorphosed dolomite or marble from Gouverneur, St. Lawrence County, New York.

The composition of this dolomite, as determined by Bole and Shaw[3] is as follows:

$MgCO_3$	43.32
$CaCO_3$	55.21
SiO_2	1.00
R_2O_3	0.46
	99.99

The dolomite was ground to pass a 100-mesh screen, mixed with fluxes, etc., in the same manner as described in the preparation of A14 composition.

[1] *Jour. Amer. Ceram. Soc.*, **7** [4], 308 (1924).
[2] *Loc. cit.*, **7** [4], 307 (1924).
[3] *Ibid.*, **5** [11], 819 (1922).

Although no sulphur is given in the analysis, the sample evidently contained traces of it, the odor of which could be detected as H_2S when the sample was broken in the jaw crusher. During crushing a very bright, distinct luminescence similar to the well-known triboluminescence of sphalerite was distinctly visible.

Brick RA14G.—Unlike the mixture of A14 using Cedarville dolomite, this Gouverneur dolomite mixture was not sufficiently plastic to be molded by the soft-mud process. A brick was made using this A14 composition pressed at 535 pounds per square inch pressure. This brick formed, dried, and burned very well. (See Fig. 40.) It had a linear shrinkage of 28.0%. The appearance of this brick was the same as those of A14 composition made from Cedarville dolomite and after two months' exposure it has remained unchanged.

Thus it appears probably true that any pure dolomite can be dead burned by this process.

Summary of Satisfactory Brick in Burn 5

This burn shows that suitable bricks when burned to cone 18 down may be made as follows:

1. Calcined D9 composition plus 0.8% sodium silicate. Hand molded.
2. Calcined A14 composition plus 23% of molasses by weight. Hand molded.
3. Calcined A14 composition plus 22.5% of molasses by weight. Pressed at 550 pounds per square inch.
4. Calcined D6 composition plus 13% by weight of a 25% dextrin, 75% water mixture. Pressed at 480 pounds per square inch pressure.

Burn 6

Magnesite brick are burned while standing on end in order to overcome the lower shrinkage of the edge in contact with the supporting brick. When burned while standing on the 9″ x $2\frac{1}{2}$″ edge, magnesite brick always shrink less on the edge in contact with the supporting brick and also crack throughout on this edge, so that Burn 6 was made having the dolomite bricks standing on end in order to overcome this distortion noted in Burn 5, where the bricks were burned while supported on edge.

Bricks made of calcined A14 composition, mixed with molasses and burned to cone 17 down in 52 hours are shown in Fig. 42.

Brick FA14.—This brick was made of calcined A14 composition, which was ground to give the following screen analysis. (See following page.)

This ground material was pressed into a brick $2\frac{7}{16}$″ x $4\frac{3}{8}$″ x $8\frac{3}{4}$″, using 554 pounds per square inch pressure and 14% of molasses as a binder.

Upon burning to cone 17 down, the brick warped very slightly. It was

slightly fused to the magnesia brick on which it stood and shrunk $^1/_4$ inch less on this end than on the upper end. The edges were very sharp and distinct, showing little or no fusion. The volume shrinkage was 16%, most of which was no doubt due to expulsion of the molasses rather than

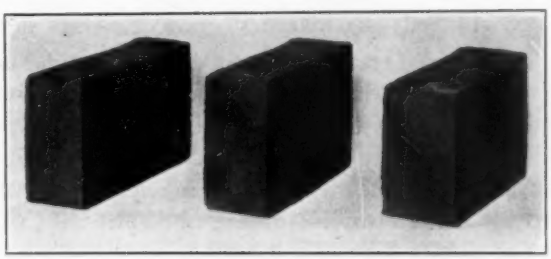
Mesh	Per cent residue
8	8.0
12	20.6
20	20.0
80	32.0
100	5.4
Fines	14.0
	100.0

shrinkage due to vitrification. This brick was very solid and firm, having a sharp ring; the only possible objection being the slightly less amount of shrinkage on the supporting end. (See *a*, Fig. 42.)

Brick HA14.—This brick was made of calcined A14 composition ground as follows:

Mesh	Per cent residue
20	0
40	18.0
80	59.0
100	5.4
Fines	17.6
	100.0

This ground material was pressed into a brick $2^{11}/_{16}''$ x $4^3/_8''$ x $8^3/_4''$, using 554 pounds per square inch pressure and 35% of molasses as a binder. This molasses was in excess to what was actually necessary for bonding purposes.



a *b* *c*

FIG. 42.

When burned to cone 17 down, this brick did not warp but again shrunk $^1/_4$ inch less on its supporting end. The edges were very sharp and distinct. The volume burning shrinkage was 25%. This shrinkage is high because of the high content of molasses used. This brick was very firm and solid, having a sharp ring. (See *c*, Fig. 42.)

Brick IA14.—This brick was made of calcined A14 composition, the same as used in Brick HA_{14}. The green brick measured $2^7/_{16}''$ x $4^3/_8''$ x

$8^3/_4$". It was pressed at 554 pounds per square inch pressure, using an unweighed amount of molasses, enough being added to easily work up the batch. This brick fused slightly to the magnesia brick on which it was supported and shrunk $^1/_4$ inch less on the supporting end. The edges were very sharp and distinct, showing no fusion. The volume shrinkage was 29%. The brick was very solid and firm, having a good ring. (See *b*, Fig. 42.)

Discussion of Burn 6

All three bricks are very good except for the smaller amount of shrinkage on the supporting end. Brick FA_{14}, using coarser grained material, warped slightly. Bricks HA_{14} and IA_{14}, using finer material, did not warp.

Only those bricks made using molasses as a binder were found to fuse to the magnesia brick. It is believed that this is due to the fact that during the early stages of the burn the molasses gradually seeps down through the brick and runs into the pores of the magnesia supporting brick. This molasses carries a small amount of dolomite with it into the magnesia brick which at higher temperatures causes the slight fusion noted with the magnesia. It was possible to knock these bricks off the magnesia bricks by tapping with a hammer, but a small, skin-like portion of the dolomite brick came off with the magnesia brick. It is suggested that these bricks be set on powdered magnesia spread over the magnesia or silica brick similar to sanding in an ordinary brick kiln to prevent sticking.

Reasons for Dolomite Stability

An analysis of compositions A14, D6 and D9 made of dolomite plus C.P. fluxes to determine the free CaO or CaO existing therein in the form of possible compounds decomposable by water such as $CaO.Al_2O_3$[1] was made as follows:

The calcined material was crushed and ground to pass a 100-mesh screen. A one-half gram sample was treated with 1,000 cc. of distilled water and thoroughly stirred. This was filtered and the residue washed with distilled water until all traces of calcium were removed. The calcium present in the filtrate and washings was precipitated by means of ammonium hydroxide and ammonium oxalate and ignited as CaO.

The results were as follows:

	A14	D6	D9
CaO	25.88%	23.44%	19.68%

Thus it is seen that the percentage of free CaO in these calcined dolomite compositions still exists in considerable amounts. The dolomite analysis shows the CaO content to be 30.2%. Since A_{14} contained 10% of flux and 90% of dolomite, the actual content of CaO in A14 before calcination

[1] Van Nostrand's *Chemical Annual*, p. 148 (1918).

is 90% of 30.2% or 27.18%; hence but 4.8% of the total lime present has been rendered insoluble when A14 composition is ground to pass a 100-mesh screen. Likewise in D_6 composition where 15% of flux is used, the actual lime content before calcination is 25.67% and after calcination is 23.44% so that 8.7% of the total lime present in D6 has been rendered insoluble. A similar calculation shows that 23.3% of the total lime present in D9 has been rendered insoluble by calcination with 15% of flux.

Composition D9 which contains 3% Al_2O_3 has more CaO in the insoluble form than D6 which contains no Al_2O_3 except the 0.5% impurity as reported in the analysis which makes the total Al_2O_3 content of D9 equal 3.4%. The SiO_2 content in both is 6%. The Fe_2O_3 content in D6 is 9% and in D9 is 6%. As shown in Fig. 1,[1] there are 4 compounds between CaO and Al_2O_3. Also the fusion tests tend to indicate a strong fluxing action of Al_2O_3 with CaO so that it is probably due to the difference in Al_2O_3 content that there is less free CaO in D9 than in D6. Of the possible compounds which could be formed in these mixtures, $CaO.Al_2O_3$ is the only one that could be found in the literature as decomposable by water; hence, no doubt, at least most of the CaO found by this analysis exists as free CaO in the mixture.

Composition A_{14} contained 4% Al_2O_3 but only 2% Fe_2O_3 and 4% SiO_2 so that it cannot be considered in this method of comparing the action of the different fluxes on D6 and D9.

The slaking of this free lime with water is considered to be the cause of cracking of bricks made from the calcined mixtures when finely ground and tempered with water. A bond tends to overcome this cracking by its binding action, and as shown in bricks DD_6 and NaD_9 which contain less free CaO than does A_{14} composition, they are very successful. It is in all probability due to the low water content of molasses that A14 composition can be successfully made into brick.

The question naturally arises as to why these compositions which appear to contain so much free lime are dead burned and do not slake when in brick form. There are several possible reasons for these phenomena which are given in discussion throughout this work. They are as follows:

1. The condition of approaching the natural composition of Breunnerite is brought about by very intimately mixing the dolomite with Fe_2O_3 and grinding very finely so that the MgO forms the stable periclase when calcined.[2]

2. The large amount of MgO present acts as an adulterant and renders the lime inert.[3]

3. The lime is overburned, that is, it is burned at a very high tempera-

[1] See "Dead Burning of Dolomite," *Loc. cit.*, **7** [1], 65 (1924).

[2] *Loc. cit.*, **7** [1], 71 (1924).

[3] *Ibid.*, 7 [1], 73.

ture cone 17, approximately 1470°C, in the presence of impurities, notably silica, so that it is rendered inactive. (*Ibid.*, 71.) These phenomena of overburning are also shown by lime treated with insufficient water to complete hydration. The unslaked portion will "burn" and become practically useless.[1]

4. A dense lime slakes more slowly than a porous lime. (*Ibid.*, 73.) The absorption of cubes A_{14}, D_6, and D_9 determined by the vacuum method were 0.47%, 2.5% and 2.4%, respectively; showing that these bodies were well vitrified and impervious to the action of water.

5. Compounds may be formed which form an envelope around these CaO grains and prevent them from slaking. Kowalke and Hougen[2] show that in burning magnesia to 1700°C, forsterite ($2MgO\ SiO_2$) crystals form a complete envelope about periclase crystals.

6. It is a known fact that the top layer of fine lime will air-slake (*i. e.*, form $CaCO_3$) and the crust of inert material so formed will prevent access of the air to the quicklime underneath, making fine lime so stable that it can be shipped in open gondola cars.

7. The stability of hydrated lime is likewise attributed to the fact that an impervious coating of air-slaked lime forms on the outside and prevents access of the air to the interior.[3] Chiefly to this cause is attributed the stability of these dolomite compositions. It is considered that a crust or envelope of calcium carbonate is formed around the small particles of free lime present, preventing their contact with water or air, thus rendering them nonsoluble. When finely ground, this protective coating is broken up and the free lime present thus rendered soluble. As stated, the free or water soluble CaO in the product ground to pass 100-mesh ranges as high as 25.88% in composition A_{14}. This water soluble CaO, at least that which exists as free CaO, is thought to be surrounded by this impervious air-slaked coating of lime, and is thus inaccessible to the action of water and air.

Absorption tests of samples A_{14}, D_6 and D_9 at definite intervals for change in weight when soaked in cold water under atmospheric pressure, after having undergone the absorption test under vacuum for one hour, gave the following results.

After soaking for 24 hours, the water in which the briquettes were immersed gave a faint test for CaO. After soaking for 72 hours, the water still gave but a faint test for CaO. The water was then changed and, after remaining in this water for 48 hours, cube A14 did not change in weight,

[1] W. E. Emley, "Manufacture of Lime," U. S. Bureau of Standards, *Tech. Paper* **16**, 77 (1913).

[2] "Crushing Strength of Magnesia-Silica Mixtures at High Temperatures," *Trans. Am. Electrochem. Soc.*, **33**, 215 (1918).

[3] Emley, *ibid.*, 16–7.

cubes D_6 and D_9 lost but 0.01 gram in weight. The water gave no test for calcium.

After drying these cubes for 24 hours at 110°C, A_{14}, D6 and D9 showed a decrease in weight from that of their original dry weight equal to 0.39%,

Hours Soaked	Cumulative Percentage Increase in Weight		
	A14	D6	D9
24	0	0	0
48	0	0	0
72	0	0.06	0.16
120	0	0	0.08

0.49%, and 0.42%, respectively. A slight scum, due to calcium carbonate, was visible on their surfaces.

Analyses for CO_2, H_2O and water soluble CaO in samples of A14 composition which had just been removed from the kiln and one which had stood in the air for 12 months were as follows:

	New sample A14, per cent	12 months' old sample A14, per cent
CO_2	2.87	6.03
H_2O	1.24	3.39
Water soluble CaO	25.88	23.73
Theoretical CaO	27.18	27.18
Combined or insoluble CaO	1.30	3.42

From the above it is seen that the percentage of CO_2, H_2O, and insoluble CaO has increased over a period of 12 months. This is due to the formation of carbonates with aging. Evidently more lime has gone into the carbonate form which will, therefore, tend to make the brick even more stable, so that instead of slaking upon standing, this brick will become more resistant to slaking. The percentage of H_2O has increased with aging, probably much of this H_2O is hygroscopic water rather than chemically combined water.

If all of the insoluble CaO were present as $CaCO_3$, the 1.3% of insoluble CaO in the new sample of A14 would require 1.02% of CO_2. This leaves an excess of 1.85% CO_2, according to the analysis. Likewise, in the old sample of A_{14}, the 3.42% of insoluble CaO requires 2.69% CO_2, thus leaving 3.34% CO_2 unaccounted for. It is possible that some of the soluble CaO may be present as the bicarbonate $Ca(HCO_3)_2$; also, no doubt, a small amount of CO_2 was left in the product after calcination. Most limestones retain nearly 0.5% of CO_2 after calcination in lime kilns.

General Conclusions

1. In this study, several compositions capable of being calcined at cone 16–17 down, to form apparently dead-burned dolomite, have been found.

2. These stable members together with their compositions are as follows:

Member	Dolomite %	Fe_2O_3 %	Al_2O_3 %	SiO_2 %
B13	90	3.04	5.82	1.14
B15	90	3.62	2.31	4.07
B21	90	....	5.32	4.68
B22	90	....	4.60	5.40
B23	90	....	2.98	7.02
A14	90	2.0	4.0	4.0
A15	90	2.0	2.0	6.0
D6	85	9.0	....	6.0
D9	85	6.0	3.0	6.0
D11	85	5.0	5.0	5.0
D13	85	3.0	9.0	3.0
D15	85	3.0	3.0	9.0
D18	85	....	12.0	3.0
D19	85	....	9.0	6.0

3. Of these members, the following can be classed as Number 1 refractories: *i. e.*, their fusion point lies above standard cone 32, which deforms at about 1770°C; B13, B15, B21, B22, B23, A14, A15, D6, D9, D11, D15 and D19.

4. Any of these compositions could, no doubt, be used as dead-burned granular dolomite.

5. These compositions are made of materials ground to pass a 100-mesh screen and thoroughly mixed before calcination.

6. Composition A_{14} can be made satisfactorily using North Carolina kaolin as a source of the SiO_2 and most of the Al_2O_3.

7. Composition D9 cannot be made using North Carolina kaolin because of slaking due to calcium orthosilicate ($2CaO.SiO_2$) formation.

8. As the percentage of flux increases up through 15%, the number and stability of the calcined dolomite flux mixtures increase.

9. Five per cent of the three fluxes Fe_2O_3, Al_2O_3 or SiO_2 is insufficient to produce a dead-burned product from this dolomite.

10. Dead-burned dolomite cannot be obtained using any one of the three fluxes Fe_2O_3, Al_2O_3 or SiO_2 alone in amounts of 5%, 10%, 15% and 40%.

11. Pure dolomites of different crystalline character can be dead burned.

12. All compositions containing 5% of fluxes have deformation points above cone 32.

13. All compositions containing 10% of fluxes have deformation points above cone 32, except the composition A17 containing 10% of Al_2O_3 alone as a flux which deforms at cone 15.

14. When 15% of the fluxes studied herein are present, compositions with fusion temperatures at cone 20 or lower are obtained when the total Al_2O_3 content exceeds 6% and Fe_2O_3 is present.

15. Al_2O_3 has by far the greatest effect in lowering the fusion temperature of this dolomite. Fe_2O_3 is next and SiO_2 has the least effect on lowering the fusion temperature.

16. These dolomite compositions without molasses will not flux with magnesite below cone 33 as shown by the fusion tests.

17. It is very difficult to make commercial sized bricks of the raw material because of the excessive volume burning shrinkage which at cone 16–17 down, averages about 70% on the dry volume basis. This high shrinkage causes cracking and deformation of the bricks.

18. Using previously calcined dolomite and then adding the fluxes and calcining is of no value because of high shrinkage due to hydrated lime.

19. Dolomite brick can be made satisfactorily as follows:

Calcine the raw materials of the compositions below to cone 17 down. Grind to pass a 20-mesh screen. Form into bricks and burn to cone 17–18 down.

RAW BATCH RECIPE

	A_{14}	D_6	D_9
100-mesh dolomite	90	85	85
Fe_2O_3	2	9	6
Al_2O_3	4	..	3
SiO_2	4	6	6

Method I—A14 composition plus 16%–23% of molasses by weight. Mold by hand or press at 550 pounds per square inch.

Method II—D6 composition plus 13% by weight of a 25% dextrin, 75% water mixture. Press into brick at 480 pounds per square inch.

Method III—D9 composition plus 20% of a 4.5% sodium silicate solution. Mold by hand.

20. When using 100-mesh raw Cedarville dolomite, water serves very well as a bond for a standard size brick.

21. Artificial bonds containing a high percentage of water cannot be used for making bricks of composition A14 because of cracking during the drying stage.

22. Cracking of the fine calcined material during drying is due to hydration of the free lime.

23. Compositions D_6 and D_9 do not appear to have the fault of cracking during drying when much water is used in the bond.

24. Tar appears to be unsatisfactory for bond for the calcined material, although it contains no water.

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(This concludes this paper on "The Dead Burning of Dolomite")

ERRATA

The following corrections in the paper by N. L. Bowen and J. W. Greig, "The System: Al_2O_3–SiO_2," **7** [4], 238 (1924), should be noted:

In title of paper and legends for Figs. 2 and 4, replace . with – "in $Al_2O_3.SiO_2$; as Al_2O_3–SiO_2.

P. 238: Footnote 2 should read "The Best Described Examples Are Those from the Island of Mull. H. H. Thomas, *Quar. Jour. Geol. Soc.*," etc.

P. 242: Legend, Fig. 4. Omit the words "After Shepherd, Rankin and Wright."

P. 245: Line 4. Table I should read "Table II."

All right-hand page headings to read as follows: "The System: Al_2O_3–SiO_2" instead of "$Al_2O_3.SiO_2$."

CERAMIC ABSTRACTS

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[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

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Abrasives

Vitreous enameling in the electric furnace. J. L. McK. Yardley. *Elec. World*, **82**, 327; *Chem. Met. Eng.*, **29**, 55–8(1923).—Recent furnace improvements include carborundum or carbofrax brick muffle, intermittent gas fire and elec. heat. Carborundum has $^1/_8$ the thermal resistance of fire clay. In the intermittent furnace, gas is burned directly in the chambers and heated above the required temp. Then the gas is turned off and the enamel is fused under falling temp. With 500 B.t.u. gas at 50 cents the fuel cost with intermittent gas furnace is 9 cents per 100 lbs. or 10 cents per 100 sq. ft. of surface. Cost in elec. furnace will be as low if power cost is 1 cent per kw.-hr. Furnaces for watch dials, bath tubs and sheet Fe are described and other cost data given. R. J. M. (*C. A.*)

Report of Refractory Materials Committee. Jointing materials for silica refractories. D. Jones and W. Emery. *Gas J.*, **163**, 157–9(1923); *Gas World*, **78**, 646; cf. *Ceram. Abs.*, **2** [11], 255(1923).—The more nearly a jointing cement approaches in chem. compn. and phys. behavior that of the bricks with which it is used, the more satisfactory are the results obtained. Examn. was made of the effect of mixing in various proportions, fire clay, ganister and crushed silica brick, and, in some cases, of adding plaster, lime and Na_2SiO_3. Mixts. of the 3 first materials, having either equal or greater proportions of ganister to crushed silica brick, give very good jointings. A high % of the latter renders the cement mechanically weak. For the bonding material, a small % of a highly plastic refractory clay is more satisfactory than a large proportion of fire clay of a less plastic nature. No advantage is obtained by the addn. of such materials as plaster, lime or Na_2SiO_3 to a cement which is to be used at high temps. J. L. W. (*C. A.*)

Abrasive materials in 1922. L. M. Beach and A. T. Coons. U. S. Geol. Survey, *Mineral Resources of U. S., 1922*, Pt. II, 221–5(preprint No. 25, publ. Dec. 3, 1923). See *Ceram. Abs.*, **3** [4], 109(1924). E. J. C. (*C. A.*)

PATENTS

Process of treating the surfaces of crystalline mineral materials. Miner L. Hartmann. U. S. 1,482,792, Feb. 5, 1924. The process of treating the surface of cryst. mineral material which consists in heating said material in contact with a halogen salt to a temperature sufficient to produce a surface reaction between said mat. and said salt but insufficient to produce glazing of the surface of said mat.

Process for treating surfaces of crystalline mineral material. Miner L. Hartmann. U. S. 1,482,793, Feb. 5, 1924. The process of improving the bonding quality of crystalline mineral materials, which consists in moistening the material with a surface pitting acidic substance and heating to a temperature sufficient to produce a surface pitting reaction, but insufficient to produce glazing of the surface of the crystals, substantially as described.

Method of making abrasive wheels. Peter Joel Styffe. U. S. 1,485,132, Feb. 26, 1924. The method of making an abrasive wheel, comprising the steps of supporting the wheel consisting of granular abrasive and heat setting bonding material upon a substantial portion of its peripheral face by a refractory, retaining the wheel in such position and firing it while in this position to bond the abrasive grains.

Art

Forgeries of ancient stained glass. Methods of their production and detection. J. A. KNOWLES. *J. Roy. Soc. Arts*, **72**, 38–56(1923); 7 figs. G. E. B. (*C. A.*)

PATENT

Beads. C. SEIDEL and N. BOYER. Brit. 204,627, Jan. 22, 1923. Beads, especially glass beads, are rendered iridescent by coating them with resin or a resinous substance, heating to fuse the resin, and exposing them to the fumes evolved by $SnCl_4$, $TiCl_4$, or other metallic compd. producing white vapors. (*C. A.*)

Cement, Lime and Plaster

The concrete masonry house today, the fireproof house tomorrow. ANON. *Concrete*, **24**, 41–3(1924).—The concrete masonry walled house which displaces other kinds of masonry, besides frame and veneer, is one kind of development; the other is the fireproof house with concrete floors and other unburnable features. Through its district representatives in all parts of the country, the Port. Cement Assn. compiled data which show that production of concrete block and structural tile of all styles and dimensions reduced to a volume term of 8 x 8 x 16 in. blocks amounted in 1920 to 50 million; in 1921 (a more complete survey), 175 million; in 1922, 297 million; and in 1923, 385 million. The production of concrete brick in 1923 is figured at 155 million. Reducing block to brick (1 block equaling about 13 brick) the 385 million block are the equivalent of a little more than 5 billion brick, and, adding the 155 million of concrete brick, concrete building units (not including dimension stone) total an equivalent of more than 5 billion, 185 million for 1923. Compare this with an estimated common clay brick production in 1923 of 6 billion. It is not to be assumed, however, that concrete units are displacing clay brick at any such rate. Concrete building units are swelling the total of masonry construction. It is getting business that clay units might have had if the clay industry had put a greater promotional effort behind its products and had no such formidable competition. F. T. H.

Rapid slaking of lime. J. E. DUCHEZ. *Rev. Mat. Constr. Trav. Pub.*, **164**, 80–2; **165**, 104–7; **166**, 127–30(1923).—In slaking burned lime contg. silica and alumina just sufficient water is added to slake the lime but not enough to hydrate any silicates or aluminates. The quantity of water to be used can be calcd. from the empirical formula, % water by wt. $= c-1.7(a+b)/3$, in which the chem. compn. in wt. % is a SiO_2, b Al_2O_3 and Fe_2O_3, c CaO and MgO. The formula is derived from the following considerations: The compds. formed from SiO_2, Al_2O_3 and CaO in making hydraulic cements are mainly $SiO_2.2CaO$, $SiO_2.3CaO$, $Al_2O_3.3CaO$ and free CaO. In burning lime with mol. compn. x SiO_2, y Al_2O_3, n CaO, granting that the above compds. are formed the max. and minimum free lime left for hydration will be: (*a*) $x(SiO_2.2CaO) + y(Al_2O_3.3CaO) + [n-(2x+3y)]CaO$; (*b*) $x(SiO_2.3CaO) + y(Al_2O_3.3CaO) + [n-3(x+y)]CaO$. As the free lime only should be hydrated, the limits for the water content are: $[n-(2x+3y)]H_2O$ and $[n-3(x+y)]H_2O$. Converting the % chem. compn. of the lime into mol. ratios gives, $0.93a$ SiO_2, $0.55b$ Al_2O_3, $1c$ CaO. Substituting these values, the limits in wt. % are $\frac{1}{2}[c-(1.80a+1.65b)]$ and $\frac{1}{2}c-[(2.80a+1.65b)]$; the fraction $\frac{1}{2}$ being the ratio of water to lime used for slaking theoretically pure lime. Equalizing the factors in the max. limit gives the empirical formula. The calcd. values agree with the quantities used in practice:

Lime from: wt. % compn.	Tarn.	Aude.	Cantal.	Basses-Alpe
SiO_2	4.5	0.75	16.32	25.21
Al_2O_3 and Fe_2O_3	3.1	0.32	4.00	1.32
CaO and MgO	91.94	97.70	77.58	72.00

Water of hydration: wt. %				
Calcd. from formula	26.04	31.29	14.34	8.96
Used in practice	25	32	15	10

Lime crushers, hydration systems and storage bins are described with special reference to installations made by the author. L. N.

Heat balance of a rotary cement kiln. CH. BERTIN. *Rev. Mat. Constr. Trav. Pub.*, **164,** 97–100; **165,** 121–3(1923).—Calcns. are given to show that in firing a rotary cement kiln with coal the usual distribution of heat is as follows: (1) for evapn. of water 30%, (2) losses of heat through stack 14%, (3) losses by radiation from metal covering 6%, (4) losses due to cooling of the hot clinker 12%, (5) leaving 38% of the heat used for the actual decompn. of the carbonates and for starting the chem. reactions. It is recommended that where possible less water be used for mixing, that provisions be made for draining off excess water, that the stack heat be utilized in heating up the water used in mixing the raw materials, and that the air for combustion be preheated by the heat generated by the cooling clinker mass. L. N.

Manufacture of cement tile. P. LOZACH. *Rev. Mat. Constr. Trav. Pub.*, **167,** 187–9(1923).—A general description of the process of making cement tile. L. N.

Note on the use of liquid fuel in the ceramic industry. ALIX CORNILLE. *Rev. Mat. Constr. Trav. Pub.*, **167,** 142–3B(1923). L. N.

Recommended specifications for quicklime and hydrated lime for use in the manufacture of sand-lime brick. ANON. Bur. of Stand., *Circ.* **150.**—This is the 6th of a series of specifs. for the lime used in various chem. industries. To assist in the development of these specifs., the bureau has called together an Interdepartmental Conference on Chem. Lime, composed of representatives of the Geological Survey and Bureau of Mines, of the Interior Department; the Bureau of Soils, Bureau of Chemistry, Forest Service, and Fixed Nitrogen Research Lab. of the Department of Agriculture; and the Chem. Warfare Service of the War Department. The present specifs., based on a draft originally prepared by W. E. Emley, of the lime section, Bureau of Stand., has been unanimously approved by the above conference and by the Nat. Lime Assn. Either quicklime or hydrated lime may be purchased for making sand-lime brick, but the former must be completely hydrated before it can be used. Mat. of about 85% purity and reasonably low in magnesia is required. The lime must also be reasonalyb fresh, as indicated by a low content of carbon dioxide. Methods of anal. are given in detail. H. F. S.

Wall plaster: Its ingredients, preparation and properties. ANON. Bur. Stand., *Circ.* **151.**—The art of plastering is intimately connected with the comfort and safety of the occupancy of buildings, yet few outside the trade understand the nature of the mat. and the details of the work required to produce the desired results. The recently aroused interest in building has carried with it interest in plastering. Much information about the factors which enter into successful plastering was found available in the trade. This paper represents an attempt to collect and correlate this information for the public benefit. To assist in the work, a committee known as the Bureau of Standards Plastering Conference was organized of men most familiar with the different phases of the subject. From the information thus furnished, and from lab. research work, we have been able in many cases to explain not only how an operation is conducted but also why this is the best way of doing it. It is recommended that furring be used when plastering exterior masonry walls, to prevent damage due to condensed moisture. When masonry walls are to be plastered without furring, the surface of the masonry should be true and clean and of proper degree of wetness. Specifications and directions for erecting are given for wood, wire and metal lath, and gypsum plaster board. Descriptions and specifs. are given for the ingredients of plaster—lime, gypsum, cement, sand, hair,

water, etc. The chief properties of the wet mix. are discussed, as they affect the quality of the finished plaster. Complete directions are given for the mixing of the ingredients and the application of the wet mix. to the wall. The chief properties of the hardened plaster are discussed as they affect the comforts and safety of the occupant. Different kinds of decorative features are described. Some of the common defects are described, and their causes and remedies suggested. Attention is called to the factors to be considered when selecting materials for plastering in order that they may be best adapted to the particular case. H. F. S.

Recommended specifications for quicklime and hydrated lime for the manufacture of silica brick. ANON. Bur. Stand., *Circ.* **153.**—A brief description of the way in which lime is used in the manuf. of silica brick is followed by a gen. statement as to the quality of lime required. The stand. of quality is set at 92% based on the nonvolatile matter, with max. limits of 5 and 10% carbon dioxide, depending upon whether the sample is taken at point of shipment or of destination. Complete directions for sampling and testing are included. H. F. S.

The chemico-technical and mechanical properties of caustic magnesite. ANON. *Bäumaterialien-Markt. Leipzig*, **36** and **38**(1921).—This publication consists of two lectures delivered before the general meeting of the Verband Deutscher Steinholzfabrikanten in Nurnberg dealing with the tests of caustic magnesite as a building material. The researches were carried out by L. Jesser in collaboration with chemists of the laboratory of the Austro-American Magnesite Company. In determining the value of caustic magnesite for use as a building material chemical tests are not adequate. The important tests are for fineness of grind, hardening characteristics, volume stability and tensile strength. The fineness test is made by screening through two sieves of widely different sizes of mesh opening. The test for set or hardening is a "pat" test carried out as follows: 100 grams of the magnesite is kneaded with about 40 to 50 cc. of a 20° Bé magnesium chloride solution to a standard consistency. The mass is formed into tapering pats on a glass plate. The resulting hardness is then determined with the Vicat needle. The material should have a setting time of between 2 and 5 hours. In making this test the pat should be covered to prevent rapid drying. The test for volume stability is made by mixing the magnesite with pine sawdust in the ratio of 1 to 2 by volume (3 to 1 by weight) moistening with 20° Bé magnesium chloride solution and making into forms by gentle pressing. After 24 hours the samples are removed and measured. It is assumed that the formation of the Sorel Cement is complete in this time. The measurements are kept up every day for 1 month. The most significant results are obtained, however, during the first 10 or 14 days. The volume change should not amount to an expansion of more than .15% of the length nor to a contraction of more than .25% of the length. The air to which the specimens are exposed should not vary more than 6% from a relative humidity of 60%. The sawdust should consist of 50% 0–.1 min., 10% 1 to –1.5 min., 40% 1.5–2 min. The test for tensile strength is to be made on the same material as was used in the preceding test. Tests should be made after 3, 7 and 56 days. After 3 days the tensile strength should be more than 8 and less than 25 kg. per sq. cm.; after seven days not less than 20 kg. per sq. cm. and after 56 days not less than 40 kg. per sq. cm. M. E. HOLMES

The action of sugar on cement mortars. CONSTANTIN TSOUNTAS. *Bull. inst. Egypte*, **5**, 157–62(1923).—Expts. confirmed previous statements as to the deteriorating effect of the presence of sugar in the water used for making cement mortars. The time required for setting was considerably shortened. The resistance, in the hot water test of Le Chatelier, was destroyed. The resistance was lowered as the sugar content increased to the point where, with high concns., the mortars completely disintegrated. This effect of sugar is a serious factor only in the neighborhood of sugar mills. P. R. D. (*C. A.*)

Fused cement or "Alcement." RUD. CHRISTIANI. *Teknisk Ukeblad*, **41**, 143–66 (1923).—The author gives the procedure for manufg. fused cement. The fusion is carried out in elec. furnaces or in water-jacketed furnaces. The raw materials are bauxite and lime. The av. compn. of alcement is approx. 40 CaO, 10 SiO_2, 40 Al_2O_3 and 10% Fe_2O_3. The main chem. constituents are Ca aluminates. The compn. of the raw mixt. can be varied within very wide limits and still good cements be obtained. The rate of cooling has a great influence upon the qualities of the fused cement. Per ton of alcement 2000 kw. hr. + 100 kg. electrodes is required for elec. fusion and 750 kg. coke for fusing in water-jacketed furnaces. A report is given of a series of assays made to compare the alcement with com. Port. cements. Alcement hardens much more quickly than do the com. cements. By tests with neat cement as well as with usual mortar mixts. the alcement showed greater tensile and crushing strengths than com. cements, in most cases even when aged for more years. The results are given in several tables. Only small differences are found between the strengths obtained by water-hardening and those obtained by air- or combined hardening. Driving tests to compare the resistance of poles molded from ordinary concrete and from alcement concrete and aged for different periods showed a considerable difference in favor of the latter. This is also said to be completely sound in all cases. It is more acid-proof than Portland cement. Neat alcement evolves a considerable amt. of heat during the binding, but in concrete mixts. this effect is of no importance. The Dan. State Lab. for Testing Materials found the following compn. of a sample of alcement: SiO_2 10.0, Al_2O_3 37.8, Fe_2O_3 0.2, FeO 5.5, FeS 0.6, TiO_2 1.7, CaO 42.4, MgO 0.3, SO_3 0.7, and moisture 0.3%.

C. H. A. S. (*C. A.*)

Enamel

Wet-process enamels for cast iron. R. R. DANIELSON AND H. P. REINECKER. Bur. Stand., *Tech. Paper* **246.**—Part of the results given in this paper are reported in *Jour. Amer. Ceram. Soc.*, **5**, 647–69(1923). Wet-process enameling of cast iron is becoming of importance because of its application to the enameling of stove parts, sanitary fittings, and hardware. This paper is a report of an extended investg. of wet-process enamels for cast iron, both with and without the use of ground coat. Compns. used in dry-process enameling have served as a basis for the work. The effect of varying methods for prepn. of the frits, mill additions, and relation of compn. of the enamel to such properties as adherence, texture, and opacity have been carefully studied. *Ground coats.*—Sintering of most ground-coat frits has been found desirable in order to develop best adherence of the enamels to the casting. Clay gave best results as a mill addition

GROUND COATS

Batch Compns. of Frits

Enamel	Flint	Borax	Sodium nitrate	Soda ash	Red lead	Boric acid
Rg-1	69.90	36.96	6.95	..	8.17	..
Rg-17	69.90	36.96	6.95	..	4.08	7.08
Rg-18	69.90	26.07	6.95	3.04	12.24	..
Rg-25	69.90	26.07	6.95	9.88	8.17	..
Rg-26	66.30	36.96	6.95	..	8.17	6.37

for the ground coats and flint and feldspar were found to be less satisfactory. Excessive additions of clay or flint produced flaking of the ground coat, while feldspar tended to develop blistering. About 15% of clay or 10% each of clay and flint are recommended as mill addition for the ground coat. Excessive additions of any one flux were not desirable and best results were obtained in more or less definite proportions. Sodium

oxide in excess of about 10% gave rise to blistering. Boric oxide increased the firing range of the ground coat and was preferable to lead oxide on this account, although it tended to promote crawling of ground coats high in boric oxide if they were applied somewhat heavily. The best ground coats developed are given in the accompanying typical batch compns.

Mill additions.—15% of clay or 10% each of clay and flint based on the wt. of the frit, with such additions of water as may be necessary. *Cover enamels.*—These were smelted by the usual method for enamels. The mill additions consisted of 5% of clay, 8% of tin oxide, and 45% of water, all based on the wt. of the dry frit. For best results the cover enamel must be adapted to the ground coat in refractoriness. Boric oxide increased the firing range of the enamel, but tended to promote crawling, although this was less pronounced in the case of the more fusible compn. Boric oxide improved the capacity when substituted for such fluxes as sodium and lead oxide. Cryolite increased capacity, but additions above 10% tended to promote crawling. The following compns. are typical of those which gave satisfactory results:

WHITE COVER ENAMELS

Batch Composition of Frits

Enamel	Feld-spar	Flint	Borax	Sodium nitrate	Red lead	Zinc oxide	Fluor-spar	Cryo-lite	Boric acid
R-1	38.0	12.0	24.52	6.20	3.86	16.42	6.0	5.5	..
R-11	33.0	12.0	24.52	6.20	3.86	21.60	6.0	5.5	..

WHITE COVER ENAMELS

Batch Composition of Frits

Enamel	Feld-spar	Flint	Borax	Sodium nitrate	Soda ash	Red lead	Zinc oxide	Fluor-spar	Cryo-lite	Boric acid	Barium carbonate
R-1	38.0	12.0	24.52	6.20	3.86	16.42	6.0	5.5	5.0	..	..
R-11	33.0	12.0	24.52	6.20	3.86	21.60	6.0	5.5	5.0	..	..
R-14	38.0	12.0	10.90	6.20	7.70	21.60	6.0	5.5	5.0	..	..
R-18	33.0	12.0	24.52	6.20	3.86	16.42	6.0	5.5	10.0	..	..
R-28	40.0	..	54.5	5.95	..	10.3	5.0	5.5	..	8.85	4.5

Single-coat colored enamels.—These enamels are smelted in the same manner as used in the prepn. of the white cover enamels. The effects of the various ingredients are very similar to those noted in the case of white cover enamels. Suitable mill additions consist of 4% of clay, 50% of water, and the necessary amts. of color oxide to give the colors desired. The feldspar type of enamels are apparently more satisfactory than those containing flint as the sole refrac. The following compns. are typical of those which have given very satisfactory results:

SINGLE-COAT COLORED ENAMELS

Batch Compn. of Frits

Enamel	Feldspar	Borax	Sodium nitrate	Red lead	Soda ash
Ro-6	47.05	36.94	4.63	27.81	7.64
Ro-5	47.05	50.57	4.63	22.71	3.90

Single-coat white enamels.—In the production of white single-coat enamels it is necessary to develop max. opacity in the frit, since the addition of more than 3 or 4% of tin oxide in the mill batch caused blistering of the enamel when applied to the iron. Suitable mill additions for enamels of this type are as follows: Clay, 4%; tin oxide, 4%; and water, 45%. In no case were the results with the single-coat white enamels as satisfactory as

those obtained with a white enamel applied over a ground coat, particularly in regard to the opacity. The following enamels are typical of those which gave the most satisfactory results:

SINGLE-COAT WHITE ENAMELS

Batch Compn. of Frits

Material	Ro-16	Ro-38
Feldspar	45.05	45.05
Borax	50.57	39.67
Sodium nitrate	4.63	4.63
Red lead	22.71	22.71
Soda ash	3.85	6.87
Antimony oxide	2.00	2.00
Cryolite	0.00	4.00

Mill Batch

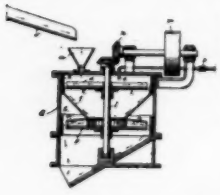
Frit	100.0
Clay	4.0
Tin oxide	4.0
Water	45.0

H. F. S.

Recommended specifications for ceramic whiting. ANON. Bur. Stand., *Circ.* **152.** —This is the 5th of a series of specifs. for the kinds of lime required by different chem. industries. The preceding 4 dealt, respectively, with lime used in cooking rags, in causticizing and in the manuf. of sulphite pulp and glass. This deals with lime used in making glazes, enamels, and similar ceramic products. Ceramic whiting is really calcium carbonate, with or without a small amount of magnesium carbonate, but it performs the function of lime. It should contain not less than 97% of carbonates, and should be very fine, so that 98% of it will pass a No. 200 screen. H. F. S.

PATENT

Method and apparatus for granulating liquid slag. EMIL OPDERBECK. U. S. 1,483,241, Feb. 12, 1924. Method for granulating liquid slag, consisting in feeding the liquid slag onto a centrifugally operating expelling element, capable of impelling the slag against an abutment, and in supplying water onto said element in quantities limited by the amount which the heat supplied by the slag is capable of converting into steam, to cause the granulation of the slag into dry slag sand.



Glass

The production of colorless glass in tank furnaces. A. COUSEN AND W. E. S. TURNER. *Glass Worker*, **43** [19], 15(1924).—Meeting of the Soc. of Glass Tech., Jan. 16, 1924. Glasses containing arsenic and decolorized with selenium turn yellow when exposed to sunlight while glasses originally yellow, due to selenium without arsenic, become bleached by sunlight. Yellow selenium glasses reheated to 500° to 600°C become deeper in color. When pink selenium glasses containing arsenious oxide or sodium nitrate are reheated to 500° to 600°C a loss of color occurs. R. J. M.

The new Edward Ford plate glass plant. HENRY W. HESS. *Glass Worker*, **43** [23], 11 (1924).—The plant has 16 furnaces of 20 pots each. Grinding machines by Hooven, Owens, Rentschler Co., casting tables by Rosedale Foundry & Mach. Co., leer by J. W. Cruikshank Eng. Co., Morgan gas producers, coal handling equipment by

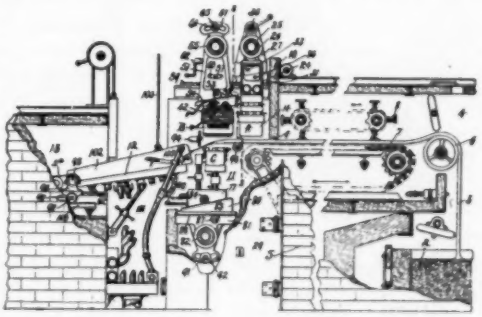
R. H. Beaumont Co., a Proctor and Schwartz drier for pots and Babcock & Wilcox Co. boilers. R. J. M.

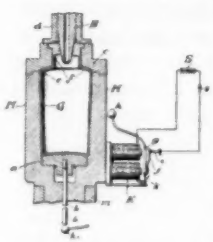
The use of selenium as a decolorizer. R. R. SHIVELY. *Glass Indus.*, **5**, 26–7 (1924).—As a decolorizer $^1/_8$ to 1 oz. Se per 1000 lbs. sand is required. A neutral fire should be maintained in tanks when Se is used. The hotter the tank the less Se is required. Not more than 42 lbs. soda ash per 100 sand should be used in the batch or a dark coloration occurs with Se. D. E. S.

The Department of Glass Technology, Sheffield, England. W. E. S. TURNER. *Glass Indus.*, **5**, 39–40(1924). D. E. S.

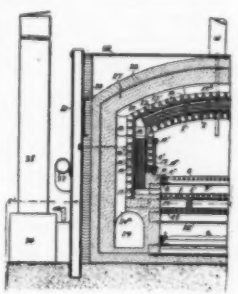
PATENTS

Method and apparatus for forming glass. ROBERT M. CORL. U. S. 1,483,336, Feb. 12, 1924. The method of forming sheet glass, which consists of continuously drawing a thick mass of glass in sheet form from a molten source of supply, the sheet mass being drawn in a plane at an upward angle to the surface of the molten mass, and, while conveying the sheet mass away from the drawing source and maintaining heat therein, applying a converting heat to the sheet mass to continuously flow a sheet of predetermined thickness therefrom and then conveying the thinned sheet through a gradually reducing temperature. The combination with a furnace of the class described from which a column of metal feeds, of a shaft extending transversely of the column and to one side thereof, and a heater carried by said shaft for adjustment lengthwise thereof to place it in operative or inoperative relation to said column. The combination with a furnace from which a sheet of glass continuously passes, of a substantially horizontal table for supporting said sheet at a predetermined distance from the furnace as it passes therefrom, the delivery end of said table being pivoted and the receiving end thereof being mounted for vertical swinging adjustment to vary the point of contact of the sheet therewith, the table having its sheet contacting surface corrugated, and means for tiltingly adjusting the table. (Cf. *Ceram. Abs.*, **3** [2], 40 (1924).)





Method of molding glassware. JOHN A. MILLIKEN. U. S. 1,482,760, Feb. 5, 1924. The method of molding glassware, which comprises introducing molten glass into a mold and causing it to take the form of the mold, and simultaneously applying to the mold a succession of blows. The method of producing a smooth finish on glassware, which comprises introducing molten glass into a mold, and vibrating the mold while the glass is in a plastic condition.



Annealing leer or furnace. ROBERT D. PIKE. U. S. 1,486,265, Mar. 11, 1924. A glass annealing leer comprising a muffle, enclosed passageways formed in the walls of he muffle and communicating with the interior thereof,

those obtained with a white enamel applied over a ground coat, particularly in regard to the opacity. The following enamels are typical of those which gave the most satisfactory results:

SINGLE-COAT WHITE ENAMELS

Batch Compn. of Frits

Material	Ro-16	Ro-38
Feldspar	45.05	45.05
Borax	50.57	39.67
Sodium nitrate	4.63	4.63
Red lead	22.71	22.71
Soda ash	3.85	6.87
Antimony oxide	2.00	2.00
Cryolite	0.00	4.00

Mill Batch

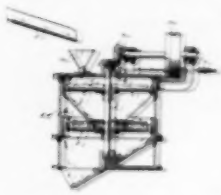
Frit	100.0
Clay	4.0
Tin oxide	4.0
Water	45.0

H. F. S.

Recommended specifications for ceramic whiting. ANON. Bur. Stand., *Circ.* **152.** —This is the 5th of a series of specifs. for the kinds of lime required by different chem. industries. The preceding 4 dealt, respectively, with lime used in cooking rags, in causticizing and in the manuf. of sulphite pulp and glass. This deals with lime used in making glazes, enamels, and similar ceramic products. Ceramic whiting is really calcium carbonate, with or without a small amount of magnesium carbonate, but it performs the function of lime. It should contain not less than 97% of carbonates, and should be very fine, so that 98% of it will pass a No. 200 screen. H. F. S.

PATENT

Method and apparatus for granulating liquid slag. EMIL OPOHRBECK. U. S. 1,483,241, Feb. 12, 1924. Method for granulating liquid slag, consisting in feeding the liquid slag onto a centrifugally operating expelling element, capable of impelling the slag against an abutment, and in supplying water onto said element in quantities limited by the amount which the heat supplied by the slag is capable of converting into steam, to cause the granulation of the slag into dry slag sand.



Glass

The production of colorless glass in tank furnaces. A. COUSEN AND W. E. S. TURNER. *Glass Worker*, **43** [19], 15(1924).—Meeting of the Soc. of Glass Tech., Jan. 16, 1924. Glasses containing arsenic and decolorized with selenium turn yellow when exposed to sunlight while glasses originally yellow, due to selenium without arsenic, become bleached by sunlight. Yellow selenium glasses reheated to 300° to 600°C become deeper in color. When pink selenium glasses containing arsenious oxide or sodium nitrate are reheated to 500° to 600°C a loss of color occurs. R. J. M.

The new Edward Ford plate glass plant. HENRY W. HESS. *Glass Worker*, **43** [23], 11 (1924).—The plant has 10 furnaces of 20 pots each. Grinding machines by Hooven, Owens, Rentschler Co., casting tables by Rossdale Foundry & Mach. Co., lear by J. W. Chalkshank Eng. Co., Morgan gas producers, coal handling equipment by

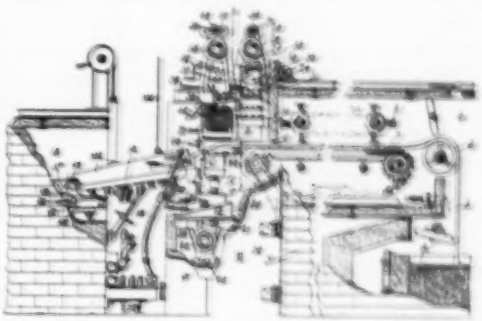
R. H. Beaumont Co., a Proctor and Schwartz drier for pots and Babcock & Wilcox Co. boilers. R. J. M.

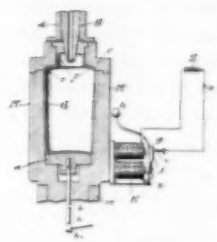
The use of selenium as a decolorizer. R. R. Sweely. *Glass Indus.*, **5**, 26–7 (1924).—As a decolorizer $\frac{1}{4}$ to 1 oz. Se per 1000 lbs. sand is required. A neutral fire should be maintained in tanks when Se is used. The hotter the tank the less Se is required. Not more than 42 lbs. soda ash per 100 sand should be used in the batch or a dark coloration occurs with Se. D. E. S.

The Department of Glass Technology, Sheffield, England. W. E. S. Turner. *Glass Indus.*, **5**, 39–40 (1924). D. E. S.

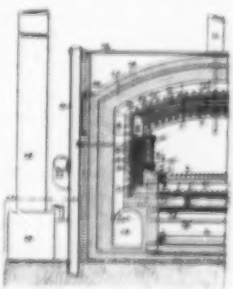
PATENTS

Method and apparatus for forming glass. Robert M. Cox. U. S. 1,483,330, Feb. 12, 1924. The method of forming sheet glass, which consists of continuously drawing a thick mass of glass in sheet form from a molten source of supply, the sheet mass being drawn in a plane at an upward angle to the surface of the molten mass, and, while conveying the sheet mass away from the drawing source and maintaining heat therein, applying a converting heat to the sheet mass to continuously flow a sheet of predetermined thickness therefrom and then conveying the thinned sheet through a gradually reducing temperature. The combination with a furnace of the class described from which a column of metal feeds, of a shaft extending transversely of the column and to one side thereof, and a heater carried by said shaft for adjustment lengthwise thereof to place it in operative or inoperative relation to said column. The combination with a furnace from which a sheet of glass continuously passes, of a substantially horizontal table for supporting said sheet at a predetermined distance from the furnace as it passes therefrom, the delivery end of said table being pivoted and the receiving end thereof being mounted for vertical swinging adjustment to vary the point of contact of the sheet therewith, the table having its sheet contacting surface corrugated, and means for tiltingly adjusting the table. (Cf. *Ceram. Abs.*, **3** [2], 40 (1924).)





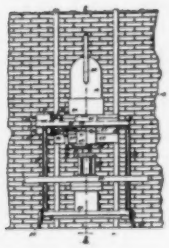
Method of molding glassware. John A. Milliken. U. S. 1,482,760, Feb. 5, 1924. The method of molding glassware, which comprises introducing molten glass into a mold and causing it to take the form of the mold, and simultaneously applying to the mold a succession of blows. The method of producing a smooth finish on glassware, which comprises introducing molten glass into a mold, and vibrating the mold while the glass is in a plastic condition.



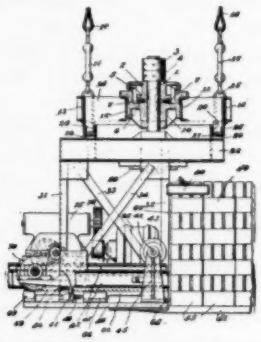
Annealing leer or furnace. Robert D. Pike. U. S. 1,486,265, Mar. 11, 1924. A glass annealing leer comprising a muffle, enclosed passageways formed in the walls of he muffle and communicating with the interior thereof,

said passageways being so arranged as to receive heat transmitted from the walls of the muffle so as to cause convection currents to be circulated over the articles within the muffle.

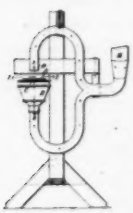
Method of and apparatus for feeding molten glass into molds. ALEXANDER L. SCHRAM. U. S. 1,484,907, Feb. 26, 1924. The method of gathering glass from a flowing stream, which consists in establishing a regulated flowing stream of glass, simultaneously severing and enlarging the stream below the outlet at intervals, utilizing the enlarged severed end of the stream as a moving plastic support for the on-coming stream of glass and a portion of the gathered mass, bodily arresting the downward movement of the accumulated mass until a sufficient quantity to make the desired article has been accumulated, simultaneously releasing the accumulated mass on its bottom and shearing the stream above the accumulated mass, and lastly releasing the accumulated mass on its sides.



Bricksetting machine. GRAFTON E. LUCE. U. S. 1,487,688, Mar. 18, 1924. Brick handling app. of the kind described, consisting in means to engage and lift a stack of brick, including means to contact with substantially the central portion of the foundation rows of brick in the stack, said brick engaging means having mechanism adapted to move the same under the brick while the carrier is stationary for loading the brick stack onto the carrier, said brick engaging means being movable rearwardly to release the brick stack for unloading.

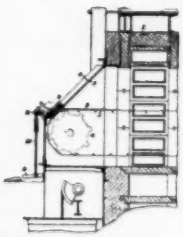


Sealing metal to glass. NAAMLOOZE VENOOTSCHAP PHILLIPS GLOEILAMPENFABRIEKEN (Eindhoven, Holland). Brit. 202,941, Oct. 25, 1922. For sealing leading-in wires, etc., a ring or cap of chromium iron alloy is used, having an expansion coeff. approx. that of glass. Various uses are indicated. Lead-in wires may be welded to the metal, which seals easily to glass. W. M. C.



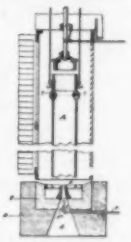
Heat treatment of glass articles. JESSE T. LITTLETON, JR. U. S. 1,483,461, Feb. 12, 1924. The hereinbefore described method of heat treatment of pressed glass articles to increase their thermal and mechanical endurance which consists in heating the article after pressing to equalize the temperature of different parts thereof, and in then rapidly uniformly cooling the article from a substantially uniform temperature above the annealing temperature of the glass of which it is composed by high velocity air jets directed on substantially the entire surface of the article.

Process of and mixture for making glass. ALEXANDER L. DUVAL D'ADRIAN. U. S. 1,482,389, Feb. 19, 1924. A glass-forming mixture containing iron and a chlorine compound adapted to act as an oxidizing agent.

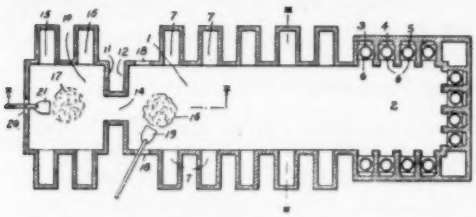


Charging doors for leers. EDWIN E. MILNER. U. S. 1,484,521, Feb. 19, 1914. An annealing leer having a charging opening, inclined frame members arranged across such opening and spaced transversely from each other, a charging door pivotally mounted between each pair of said frame members and arranged to close upwardly and outwardly against said members, each of said doors having a counterweight substantially balancing the door but arranged to normally hold it in closed position, together with separate actuating means for opening each of doors, substantially as described.

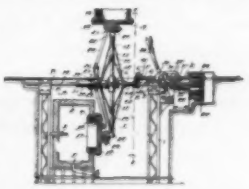
Manufacture of glass cylinders. CLYDE S. ROBB. U. S. 1,484,339, Feb. 19, 1924. In apparatus for drawing glass cylinders, a batch containing vessel, a conduit extending upwardly therethrough opening directly within the formative zone of the article being drawn and in open communication with the atmosphere below, and an air supply pipe leading to but spaced away from said conduit to supply air upwardly through the conduit while allowing for return flow of excess air backwardly through said conduit and around said pipe.



Borosilicic acid glass. KITSUZO-FUWA AND TOKYO DENKI KABUSHIKI KAISHA. Japn. 42,161, Mar. 31, 1922. The glass contains SiO_2 66.0–67.5, Al_2O_3 1.0–1.75, Na_2O 7.0–8.0, and B_2O_3 22.0–24.0%. It resists sudden change of temp., *e. g.*, it can be heated to 290° and dipped into H_2O at 23° without cracking. It adheres to W-wire and is resistant to efflorescence. It is easily worked with an ordinary coal-gas burner. (*C. A.*)

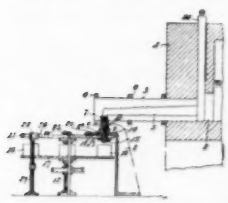


Glass-melting tank. HARRY G. SLINGLUFF. U. S. 1,486,992, Mar. 18, 1924. The combination with a regenerative glass melting tank having a melting end and a discharge end of means for supplying molten glass to said melting end of the tank. The process of operating a regenerative glass melting furnace which consists in supplying batch to the melting end of such furnace and also feeding molten glass into such melting end to the rear of said batch.



Glass-drawing device. WILLIAM WESTBURY. U. S. 1,484,101, Feb. 19, 1924. The combination of a heating kiln having an opening in a vertical wall thereof, a carrier rotatable on a horizontal axis, means for rotating said carrier, pots tiltably mounted on the carrier, eccentric mechanism operative on the rotation of the carrier for reversely tilting the pots between vertical and horizontal positions, and means for sliding the carrier back and forth to move a vertically disposed pot into and out of the kiln opening.

Automatic flow for glass tanks. WILLIAM H. MCSWAIN and HARRY W. MCSWAIN. U. S. 1,484,952, Feb. 26, 1924. An automatic flow for glass, comprising, in combination with a glass tank, a spout leading from the tank, a horizontal stand located beneath said spout and having a vertical passage therethrough, means for conducting glass from said spout to said passage, a rotating table having the edge portion thereof in closely underlying relation to said stand and having oblong openings in said edge portion, said openings being located to be successively carried by rotation of the table into register with said passage for receiving glass from the latter, a shear, means for actuating said shear across the lower end of said passage at a definite point in the registration of each table-opening with said passage, a second table located beneath the first table and molds carried by the second table in position to receive charges of glass detached by said shear.



Glass furnace. SADAJIRÔ KÔNO. Japn. 41,629, Jan. 31, 1922. Addn. to 35,150. A small furnace fixed to the main one for holding clear melted glass has a delivery orifice in the bottom, in which a rod rests. By the piston-like motion of the rod, a definite

quantity of melted glass is pushed away from the orifice, and is received in a mold of a suitable form.

Glass. TOSAKU YOSHIOKA. Japn. 41,227, Dec. 22, 1921. Addn. to 40,242 (*Ceram. Abs.*, **2** [7], 155 (1922)). Superheated steam is passed into a mixt. of 100 parts of SiO_2, 22 parts of limestone, and 33 parts of NaCl, heated in a revolving furnace at about 700°. The NaCl is decompd., producing HCl gas, and the SiO_2 is changed into Na salt. Then the mixt. is heated more highly and melted to glass. The mixt. is liable to become powdery and prevents the passing of steam; this difficulty is removed by mixing 2–3% CaO paste with the original mixt.

Etching glass. NAAMLOOZE VENOOTSCHAP PHILLIPS GLOEILAMPENFABRIEKEN. Brit. 189,763, Nov. 8, 1922. A process for producing transparent markings on frosted glass, such as trade marks on lamp bulbs, consists in printing or stamping the required design on the glass in an acid-resist and then etching the glass. The resist may be composed of "Lanoline," beeswax and resin with or without resin-oil and horse-fat, and is preferably applied to the glass in a fused state.

Heavy Clay Products

Construction features of importance to clay plants. T. W. GARVE. *The Clayworker*, **80**, 442–5(1923).—See *Jour. Amer. Ceram. Soc.*, **6**, 961–71(1923). J. W. H.

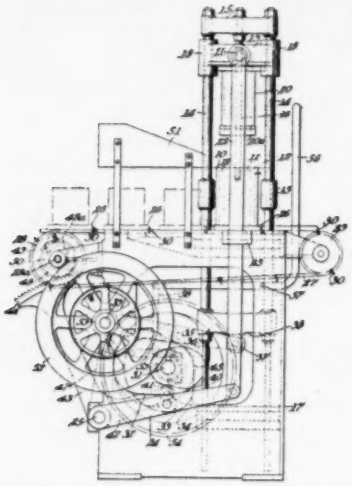
A new French system of brick manufacture. ANON. *Brit. Clayworker*, **32**, 256–60(1923).—Dry press brick plants at Charleroi, Belgium and Lens, France, using a patented "humidicator" are described. The apparatus is designed for adding a small measured percentage of water to clay which has been previously dried and ground to a fine powder. It comprises three shallow pans, one above the other, fixed to the frame of the machine. Each pan is provided with a number of steel blades fixed to arms keyed on a central vertical rotating spindle, and so disposed as to thoroughly churn the powdered clay in order to expose every part of it to the finely atomized water blown downward upon it from a number of fine jets. The water passing by gravity from a graduated tank or container, meets at the jets with a blast of air under pressure and is blown as an invisible spray on the ground clay in the top pan. A stream of the clay is delivered, at a measured rate, into the top pan near its center. The revolving blades gradually pass the clay from the center to the periphery where openings are provided to allow it to fall into a second pan. A similar set of blades, revolving on the same vertical spindle, churn the clay in the second pan and at the same time pass it to the center. It then falls through openings in the third pan, which is provided with a third set of blades. These repeated churnings effect a uniform mixture of the moisture with the clay. The methods of mining, grinding and screening at Lens are of interest. The clay used at this plant is a sandy loam only 4′ in thickness. It is excavated with a Bondy surface excavator by means of which the clay is delivered from the clay bank by an arm fitted with a conveyor into wagons running on rails. After passing through rolls the clay is run through a drying tube. This machine is 49′ long and 5′ 9″ diam. and is encased in brickwork except where the two carrying rings and the driving gear ring occurs. The carrying rings or trunions allow a smooth turning movement. A furnace built at the end where the clay enters provides the heat for drying. The hot gases go with the clay from the hot end to the dry end and are exhausted into a chimney by an induced draft fan. At the dry end the clay, still warm, passes directly into a large ball mill and is ground to a size of about 30 mesh. The ball mill screens the clay to the required fineness and it is conveyed by belt conveyors to two humidicators, each of which serves three presses. The hydraulic presses have gages attached to them which show a pressure of 110 tons for two bricks. H. G. S.

Proposed specifications for roofing tile. ANON. *Tonind. Ztg.*, **48**, 101–2(1924).—Roofing tile should be true in shape, having a good ring and a pure color. They should show no efflorescence or flashing. *Body.*—The body should show a uniform fracture without laminations. It should be free from lime and pyrite nodules. *Shape.*—The principle shapes are flat tile, grooved tile and plate tile besides the ridge tile. The standard dimensions for flat, plate and ridge tile are given in specifications in *Tonind. Ztg.*, **40** (1920). The sizes for grooved tile have not yet been specified. *Weight.*—The weight of normal flat tile should not be over $1^1/_4$ kgs.; that for plate tile not over 2 kgs.; and that of grooved tile not over 2.9 kgs. *Absorption.*—The average absorption of 10 tile is detd. These are thoroughly dried and then boiled in water to constant wt. The increase in weight for vitrified tile should not be over 6% and that for porous tile not over 17%. These should be designated as clay and loam tile, respectively. *Permeability.*—The permeability of tile to water is detd. in the following manner: A round piece is broken from the tile having a diam. of approx. 2 cms. larger than that of the glass cylinder which is 3.5 cms. In diam. (= 9.7 sq. cms.). The tile is trimmed with pinchers down to nearly the proper size and then is ground in a conical shape on the grind stone. The diam. of the lower portion of the test piece should be equal to that of the glass cylinder while the diam. of the upper portion should be larger than that of the glass cylinder. The glass cylinder is then cemented to the upper portion of the tile with a cement. The cement and conical sides of the tile are painted with a lacquer making them impervious to water. The glass cylinder is filled to a height of 15 cms. It is allowed to stand one hr. If drops penetrate through the tile it is considered pervious to water. *Cross breaking strength.*—The tile are placed on supports 30 cms. apart and a load is applied in the center. Standard tile must have a strength of not less than 100 kgs./cm.^{2} when dry, not less than 90 kgs./cm.^{2} when wet and not less than 80 kgs./cm.^{2} when subjected to 10 freezing treatments. The formula $3Pl/2bh^2$ is used in calculating the cross-breaking strength. *Resistance to frost.*—Roofing tile of all kinds must be resistant to frost. The tile to be tested are placed in water and frozen to —15°C for 14 hrs. and are thawed out at 20°C. This is done 25 times. The tile show no signs of disintegration. The same test is used for colored, glazed and engobe tile. *Glaze.*—The glaze should be well united with the body. Craze cracks on the glaze are permissible. The glaze should not peel from the body after long periods of time. The same specifs. apply to engobed tile. *Hardness.*—The body should have a hardness of 5 and the glazes of 7. H. G. S.

Firing with producer gas. C. F. SMITH. *Brick & Clay Record*, **63**, 770–1(1923).—Author gives excellent hints on opern. of a gas producer fired continuous chamber kiln for burning brick. Chambers are 49 ft. long, 14 ft. wide and 9 ft. high. Chambers are burned off at the rate of one every 24 hrs. For best practice the kiln should have at least 13 chambers. Coal consumption is 800 lb. per thousand g. in brick. Slack coal is the cheapest fuel but unless the producers are especially designed for its use, it cannot be used. Nut, run of mine and lump coal are satisfactory. The nut gives best results but on the other hand is hard to get. When run of mine or lump is used, the large lumps should be broken, while run of mine containing much slack should be avoided. The principal requirement of a coal for producer's work is that it be high in volatile matter. The ideal coal is one that gives off its volatile matter slowly, keeping up a steady supply from this source while the CO is coming from the fixed carbon. Th surface of the fuel bed must be watched for holes or bright spots which show that the air is channeling. Producer gas made in the type of producer generally used will deposit tar at temp. below 800°F. These temp. refer to gas as it leaves the producer. The neutral zone is between 800° and 900°F. J. W. H.

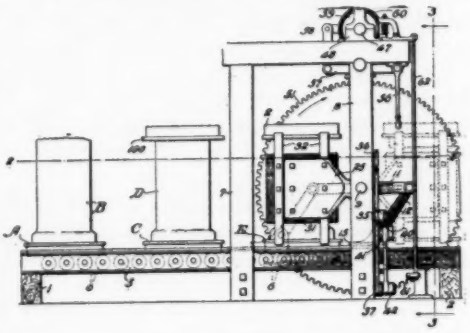
Oil firing clay products. (III-IV.) W. D. RICHARDSON. *The Clayworker*, **80**,

458–59; 552–53 (1923).—A moderate sized plant should have storage capacity for 50,000 gal. of oil, while a large plant for 100,000 gal. or more. Strainers for removal of foreign matter held in suspension should be placed (1) before entering storage tank, (2) on suction line between storage tank and pump, (3) between pump and heater, (4) finest strainer between heater and burners. Moreover the strainers should be in duplicate and in parallel, so that one may always be clean. Oil is usually heated by steam to permit of flowing. Very little steam is required as sp. ht. of fuel oil is but one-half of that of water. Oil is generally heated between 150° and 180°F. Unless oil is heated to a temp. approaching its flash point before admission to burners, the atomization is apt to be incomplete. Fluctuating oil temp. will cause flame to be unsteady. Long oil lines from storage tanks are kept warm by running the steam lines parallel in same trench or conduit. Oil pumps are of low or high pressure, electric or steam driven, of the piston or centrifugal type. Use of air (for atomization) above 5 lb. involves use of piston driven compressors, which are objectionable on account of high cost of installation and opern. Hence tendency is to use low pressures. Cuts of various pumps, strainers and blowers accompany the articles. J. W. H.

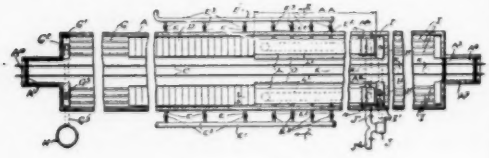


PATENTS

Tile-making machine. MORRIS KATCHER and ROWLAND MCWILLIAMS. U. S. 1,483,513, Feb. 12, 1924. In a machine for making hollow tile, the combination of two mold elements defining a vertical interspace for receiving the material to be molded, a ram having a cross-sectional configuration corresponding to the interspace, a support below the mold elements, mechanism for cyclically moving the mold elements, the ram and the support relatively to each other to compress material in the molded block upon the support, manually operable control means for setting the mechanism into motion and means for automatically stopping the mechanism at the end of a cycle of operation.



Clay-pipe-handling device. GEORGE W. GANG. U. S. 1,486,877, Mar. 18, 1924. In a machine for turning pipe sections, a rotatable shaft, a pair of cradle members keyed to said shaft and slidable thereon and means for rotating said shaft.



Method of and apparatus for flashing brick. CONRAD DRESSLER. U. S. 1,486,129, Mar. 11, 1924. The method of flashing brick in a

continuous muffle heated kiln which consists in passing fuel and air for its partial combustion into a high temperature portion of the kiln chamber to thereby maintain a reducing gas atmosphere in said kiln chamber portion and in the portion of the cooling zone of the kiln in which the brick are at a temperature high enough to result in surface oxidation if exposed to an oxidizing atmosphere.

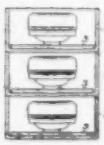
Refractories

Research on refractories in France. V. BODIN. *Ceramique*, **26**, 200–6(1923).—The following investigation was conducted in the laboratory of the Refractories Association of France. 12 silica, 7 quartzite, 5 fire clay, 10 highly aluminous, and 4 bauxite brick were tested. The chem. analyses, the permanent expans. and contraction, the reversible expans. and contraction and the softening points were determined. According to B. a good fire-clay brick with 30% Al_2O_3 withstands 1600°C for 2 hrs. without deformation; good silica and highly aluminous brick withstand a similar test at 1700°C; the linear change of a good quartzite brick should be less than 1–1½%, after heating to 1500°C for 3 hrs.; the shrinkage of a good fire-clay brick should not be over 1.5% after heating to 1600°C for 2 hrs.; highly aluminous brick should show a linear change of less than 1% when heated to 1600°C and less than 2% when fired to 1700°C. The reversible expansion tests showed only small differences in the brick and seemed to be dependent chiefly upon the chem. compns. It is largest with silica brick. Strength tests conducted on 2 cm. cubes showed maximum and minimum points when tested between 700° and 1500°C in each case with the exception of magnesite and chrome brick. The resistance of refractories to load was conducted on 2-cm. cylinders 5 to 6 cms. high. The effect of sudden temp. changes was measured on 6-cm. cubes. These were heated 1000°C and chilled in water. They were then heated to 1200°C and cooled by blowing cold air upon them. This treatment was repeated until the brick could be broken with the hands. This study showed that carborundum brick were most resistant to spalling. Brick containing carborundum and highly aluminous brick ranked next in their resistance to spalling. The brick least resistant to spalling were those containing coarse particles of silica and silica brick. H. G. S.

Brick and block making plant for the Kailan Mining Administration, China. ANON. *Iron and Coal Trades Rev.* (London), **108** [2], 916(1924).—An article with plan drawings describes a plant recently supplied by Messrs. Wm. Johnson & Sons, Ltd. (Leeds), to the Kailan Mining Administration, China, for making stiff-mud, fire and silica brick. Complete description of special and regular machy., processes, capacities, and burning is given. The installation includes mchy. for production of furnace blocks up to 14 in. sq., liners, hex. stove bricks, socketted sewer pipe, etc. R. D. L.

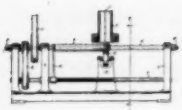
PATENTS

Artificial magnesia spinel and process of manufacture. FRANK J. TONE. U. S. 1,448,010, May 22, 1923. The process of making magnesia spinel, which consists in electrically smelting a mixt. contg. magnesia and alumina and a reducing agent at a temp. sufficient to fuse the ores and reduce a portion of the impurities in the ores to metallic form, allowing the fused product to cool, and separating the metallic impurities.



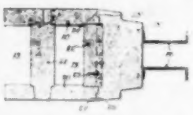
Sagger structure. FRANK J. TONE. U. S. 1,448,011, May 22, 1923. In sagger construction, a refractory structural supporting member, containing a material other and stronger than sagger material.

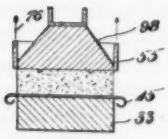
Quartz working. EDWARD R. BERRY. U. S. 1,482,455, Feb. 5, 1924. A quartz working apparatus comprising the combination of a rotatable form or mandrel, means for delivering thereto a strip of plastic quartz, means for rotating said mandrel while feeding



the same longitudinally, means for applying heat to quartz strip coiled upon said mandrel and means for applying pressure externally upon the coils of said strip to cause coalescence thereof.

Coke-oven wall structure. JOSEPH VAN ACKEREN. U. S. 1,486,401, Mar. 11, 1924. In a coke oven structure, in combination: a heating wall comprising spaced silica liner-brick sections connected together at intervals by silica tie-brick sections to form flame flues within said heating wall, the ends of said liner-brick sections being formed with jogged edges; a clay jamb-brick section positioned at the end of the heating wall and provided with companion jogged edges for engagement with the aforesaid jogged edges of the liner-brick section; and a substantially co-extending vertical joint interposed between said jamb-brick section and the adjacent tie-brick section of the heating wall, said joint composed of silica sand, to accommodate heterogeneous expansion or contraction of the jamb-brick section and the heating wall; substantially as specified.





Process of making refractory shapes. CHARLES LADD NORTON. U. S. 1,484,735, Feb. 26, 1924. That process of making molded shapes from granular material which comprises molding such a shape upon a pallet plate by forcibly projecting, as by dropping, an unrestrained mass of such material in the form of a dense swarm of discrete particles into a mold-box resting upon such plate, and removing the mold-box to leave the molded shape upon said plate.

Reflocculated product and process of preparing same. EDWARD G. ACHESON. U. S. 1,456,112, May 22, 1923. The herein described novel product prepared by subjecting a solid material susceptible of deflocculation to attrition in presence of an organic deflocculating agent and thereafter reflocculating the colloidal material in presence of the residual fine material, said product comprising an intimate mixture of non-deflocculated and reflocculated particles.

Flux or solvent for use in technical process. ALBERT ANDREW KELLY. U. S. 1,455,791, May 22, 1923. A vitreous material comprising sodium decaborate as a constituent therein.

Manufacture of refractory products from dolomite. CHARLES ARTHUR LONGBOTTOM and FREDERICK LINDLEY DUFFIELD. U. S. 1,463,399, July 31, 1923. The herein-described process for the manuf. of refractory products from dolomite which consists in artificially mixing binding mats. with the raw dolomite, shaping the products from the mixt., subjecting them to an intense shrinking heat, and finally dipping them in a medium having sealing properties.

Refractory article and method of making the same. CLARENCE J. BROCKBANK. U. S. 1,483,507, Feb. 12, 1924. A dense hard refractory graphitic article of manufacture having a body bond and a continuous glaze of non-ceramic material and of the same coefficient of expansion and other physical characteristics.

Basic refractory and process of making same. ALBERT P. MEYER. U. S. 1,483,468, Feb. 12, 1924. As a new basic refractory, an aggregation of hard, dense, angular individually fired granules of uniform nature and standardized composition, such granules being composed of a basic magnesian refractory containing enough intimately distributed fluxing material to permit bonding at open-hearth furnace temperatures.

Basic refractory and process of making same. ALBERT P. MEYER. U. S. 1,483,469, Feb. 12, 1924. As a new basic refractory for open-hearth furnaces, a granular aggregation of sharp edged, flat faced, hard, dense individually fired granules of a mixture of dolomite and bonding agent, the several granules being of uniform composition

and the amount of bonding agent being sufficient to permit bonding of the granules at the temperatures of an open-hearth furnace.

Bonded articles of magnesia and alumina. R. C. PURDY, M. F. BEECHER and A. A. KLEIN. Can. 229,902, Mar. 27, 1923. A refractory consisting of cryst. MgO and cryst. Al_2O_3 bonded together with $MgO.Al_2O_3$ is prepd. by mixing preshrunk MgO grains with finely divided Al_2O_3 and heating the mixt. below the fusion point of the latter to form $MgO.Al_2O_3$ sufficient to bond the mixt. together. (*C. A.*)

Refractory containers for molten metals. E. W. HALE. Can. 229,316, Mar. 6, 1923. The lining of a container for molten metals consists of bricks contg. at least 30% Cr. The oxide film formed on the surface of the lining protects the lining from corrosion. (*C. A.*)

Refractory cement. W. F. ROCHOW. Can. 229,684, Mar. 20, 1923. A compn. for refractory cement contains powd. SiO_2 rock, calcined SiO_2 and dry powd. Na_2SiO_3. (*C. A.*)

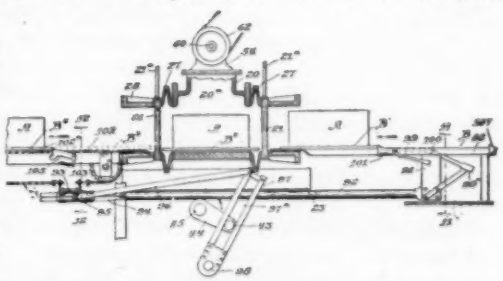
Dolomite refractories. C. A. LONGBOTTOM, F. L. DUFFIELD and W. J. REES. Brit. 191,412, July 4, 1921. Refractory products composed of dolomite are sealed against hydration after firing by immersion in molten wax, tallow, dehydrated oils or fats, or similar substances. Clay and either Fe_2O_3 or slag may be added to the dolomite in the preferred proportions of 2–10% of Fe_2O_3 and 2–15% of clay; or 2–10% each of slag and clay. The mixt. is molded into bricks and shrunk by heating to about 1500°. (*C. A.*)

Bricks and insulating stones. C. P. AASTROEM. Swed. 50,731 and 50,732, Jan. 18, 1922. A certain species of calcareous earth called "bleke" (found on the isle of Gothland in the Baltic) is passed through a fine-meshed screen, dried in the air and ground finely and then mixed with a binding substance. The latter is formed by mixing burned, finely ground "bleke" with ordinary cement. Then water is added and the mass is worked and pressed to blocks of suitable sizes and shapes, which are finally dried and hardened in the air. (Cf. 2 following abstrs.) (*C. A.*)

Insulating composition. C. P. AASTROEM. Swed. 50,733, Jan. 18, 1922. The material "bleke" (cf. above) is screened, dried and finely ground and mixed with glue water to a thick paste, which is dried and ground very finely. It is then mixed with burned, ground "bleke," clay, cement and coir. (*C. A.*)

Porous insulating material. T. A. EKLUND and C. G. LOEFVEBERG. Swed. 51,192, Mar. 8, 1922. A porous insulating material is formed by mixing "bleke" (cf. above) with cellulose. The cellulose may be partly replaced by other fibrous materials from which the incrusting substances are not removed, for instance peat fiber, peat dust, algae, straw, wood pulp, etc. (*C. A.*)

Machine for making terra-cotta blocks. MAJOR E. GATES. U. S. 1,482,646, Feb. 5, 1924. A machine for pressing plastic material into molds comprising a chamber having openings at opposite sides thereof, doors movable to close said openings, a valve for admitting a combustible mixture to said chamber, means for igniting said mixture after said doors and valve are closed, means for inserting molds into the chamber through one of said openings and means for withdrawing molds from the chamber through the other openings.



Rough-surfaced architectural pottery. ICHIRO YOKOI. Japn. 43,328, Aug. 23,

1922. Green bodies made of feldspar, granite and bog Fe ore are put in a sagger, with small spaces between them. The sagger is then filled with powd. calcined quartz. By firing it to a temp. a little below the m. p. of the body mottled wares with rough surface are obtained.

Roofing-tile kiln. TATSUJIRO KISHIMOTO. Japn. 43,050, July 11, 1922. A roofing-tile kiln has 3 chambers arranged so as to form an arch, the middle chamber being built over the passage between the other 2. The waste gases of the lower chambers are made to pass through the middle one.

Whitewares

Apparatus to determine the compression strength of insulators. H. HECHT. *Tonind. Ztg.*, **52**, 90–1(1924).—A small inexpensive hydraulic testing machine for measuring the compression strength of insulators is described. H. G. S.

Tube water colors. HANS WAGNER. *Farben-Ztg.*, **28**, 779–81(1923).—A review of the compn. and properties of aquarelle and tempera colors, especially of the desirable properties imparted to the colors by the colloidal action of slight variations in the compn. of the vehicles. Different pigments require sp. proportions of gum arabic in the vehicle to produce pastes that will not gelatinize, will not sep. on addn. of H_2O, nor produce streaky films on application, etc. The quantities of gum required for various pigments are tabulated. This quantity is dependent on the sp. gr. and degree of dispersion of the pigment. Products such as glycerol, glycol, and especially ox-gall, act as protective colloids thereby reducing the quantity of gum required, and improving the keeping qualities of the pastes in the tubes. F. A. W. (*C. A.*)

Apparatus and Equipment

Grate bar standardization. H. KUPPERS. *Trans. Feuerungstechnik*, **12** [8], 57 (1924).—Discusses the need of standardization among the estimated quarter of a million different types of grate bars. The German Standard Grate Bar Co. has taken as a basis the Schmidt changeable grate design and established a table of standards protected by patents. A single pair of these grate bars can be assembled so as to furnish an air space of 2, 4, 6, 8 and 10 mm. and experience has shown that these variations will take care of the efficient combustion of any fuel. F. A. W.

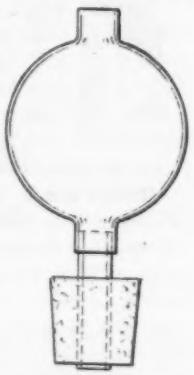
Granular carbon resistor furnaces. M. M. AUSTIN. *Ind. Eng. Chem.*, **16** [2], 156(1924).—Two types of granular carbon resistor furnaces are described, in which some disadvantages of others of this type have been overcome and the construction simplified. Method of construction and operation of both vertical and horizontal furnaces, illustrated by dimensional drawings is given. It is thought these will prove satisfactory where a cheap and efficient resistor furnace is required. R. D. L.

Furnace settings and refractory cements. F. J. WAKEM. *Ind. Eng. Chem.*, **15** [9], 893 (1923).—Chief causes for failure of furnace settings are described and remedy for each is given. Failures include plastic deformation, melting, spalling, cracking and bulging and slagging, beside the human element of poor workmanship. Special mention is made of clinkering and correct arch design. W. thinks proper selection of good refractory cements will prevent most of these troubles, if properly used. R. D. L.

Measuring viscosity. BRITISH ENGINEERING STANDARDS ASSOCIATION. *Iron and Coal Trades Rev.* (London), **108** [2], 101(1924).—The British Engineering Standards Association has issued Publication No. 188, 1923, dealing with the "British Standard Method for the Determination of Viscosity in Absolute Units," the object of which is to provide an accurate yet simple and commercially applicable method for the detn.

of viscosity of a liq. in C. G. S. units. It includes stand. dimensions for U-tube, co-axial bulb and falling sphere viscosimeters and the stand. liq. recommended for their calibration. The use and calibration of the instruments is described in detail, as well as methods for detg. viscosity of opaque liq. by means of the Lidstone Viscosimeter and by the adaptation of the tube and falling sphere viscosimeters. Copies of this publication may be obtained from the B. E. S. A., Publications Dept., 28 Victoria St., Westminster, London, S. W.1. R. D. L.

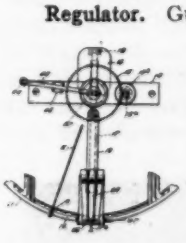
A reliable plant viscosimeter. MARTIN MARASCO. *Ind. Eng. Chem.*, **16** [2], 172 (1924).—This consists of a rubber bulb, a rubber stopper and a piece of glass tubing, assembled as shown in the sketch. The app. is dropped into the liq. to be tested and the time reqd. for submergence is a measure of viscosity. Method of calibration is given and also method for converting time in sec., using this viscosimeter, to centipoises, if it is desired to use it with different sp. gr. Advantages claimed by the author are: (1) The capillary is down in the liq. whose visc. is being measured; (2) only ordinary skill is reqd. to use it correctly; (3) it is practically unbreakable; (4) a high degree of sensitivity can be secured by selecting tubing of suitable bore; (5) it is applicable to opaque solns.; (6) it is inexpensive and easily cleaned; (7) it is always replaceable. M. states that a metal bulb and tube may be substituted, for liq. harmful to rubber. R. D. L.



Electrical precipitation of solids in stack gases. SCHROEDER. *Feuerungstechnik*, **12** [10], 73(1924).—Describes the new Oski method of electrical precipitation, the operation of which it is claimed is cheap enough to warrant consideration in the recovery of comparatively low value residues such as coal dust, etc. The apparatus is based on the theory that air in an electrical high tension field deposits its suspended solids. Instead of passing the gases between two oppositely charged electrodes as is done in most other types of electrical precipitators a wire mesh electrode of single polarity is used and a second electrode made of a semiconductor in the form of a plate and grounded is used in conjunction with it. This produces ionization and precipitation of the dust particles. A current of 40–70,000 volts and a few milliamperes is used. Advantages claimed for this system are: (1) Smallest and most uniform current consumption; (2) even current distribution through the gases; (3) remarkable high percentage of precipitation in comparison with other type apparatus; (4) cheaper installation and running expenses. F. A. W.

PATENTS

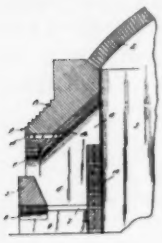
Regulator. GUY M. HAFER. U. S. 1,482,791, Feb. 5, 1924. In an elec. pyrometer for fur. a galvanometer having an oscillating needle, a pin carried by said needle, a ledge over which said pin oscillates, a member having a plurality of plungers slidably mounted therein, said plungers overlying the path of said pin, means for periodically depressing said member to cause said pin to actuate one of said plungers, an electric circuit having a switch which may be closed by one of said plungers as it is actuated, and means operable by said circuit for varying the temperature of said furnace.



Kilns, Furnaces, Fuels and Combustion

Producer practice and reaction speed. H. v. JUPTNER. *Trans. Feuerungstechnik*, **12** [7], 49(1924).—Discusses theory of combustion in gas producers and the attaining

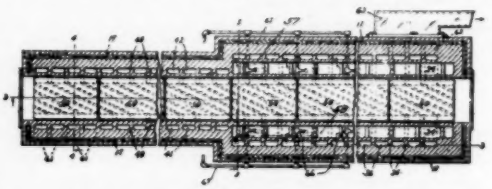
of a status of equilibrium represented by the equation $CO_2 + C \rightleftarrows 2CO$. The reaction $2CO = CO_2 + C$ takes place extremely slowly but the reverse reaction is comparatively rapid. Condition approaching equilibrium is attained in practice by increasing time of contact between the elements of combustion by (1) reducing gas velocity, (2) increasing depth of fuel bed. Speed of reaction is increased by (*a*) higher concentration of gases, (*b*) increase in temp., (*c*) use of catalytic agent. F. A. W.



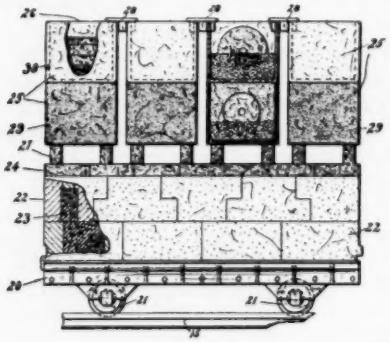
PATENTS

Kiln. IKE BIVINS. U. S. 1,486,359, Mar. 11, 1924. In a kiln, a pottery chamber having a top, an inclined arch extending to a point adjacent the upper end of the pottery chamber, a front wall having an opening therein arranged below the arch, a fire box below the arch, and a vertical baffle wall arranged between the fire box and the pottery chamber and extending above the opening, the crown being provided with a horizontally arranged sight opening above the baffle wall.

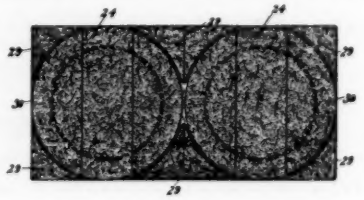
Muffle tunnel kiln. THURE LARSSON. U. S. 1,485,118, Feb. 26, 1924. A tunnel kiln comprising outer walls defining a kiln chamber for conveying ware therethrough, a combustion chamber within the kiln arranged longitudinally thereof, means providing an air conduit adjacent the combustion chamber, and means for positively circulating air through said conduit to absorb heat from the combustion chamber and transfer it indirectly to the ware.



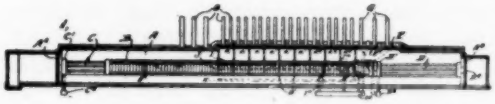
Tunnel kiln. HUGO W. H. BETH and MILTON F. BEECHER. U. S. 1,485,109, Feb. 26, 1924. In a tunnel kiln having longitudinal muffle benches in the heating chamber and a car traversing passage therebetween, the combination therewith of a car comprising a wheeled support, an imperforate refractory body portion thereon having a plane top disposed substantially on a level with said benches, small refractory blocks of high heat conductivity spaced on said car top so as not to obstruct the transverse flow of gases and stacks of refractory containers disposed on said blocks in spaced relation transversely and longitudinally of the car.



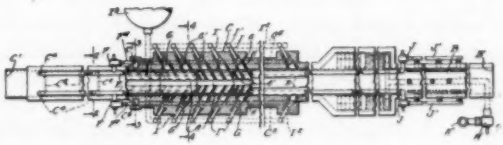
Tunnel kiln. HUGO W. H. BETH. U. S. 1,485,110, Feb. 26, 1924. A tunnel kiln comprising a movable kiln car platform, a refractory turntable mounted thereon to rotate in a horizontal plane, a plane-surfaced layer of superrefractory material on said table to support the ware, a refractory superstructure supported upon said movable platform partially surrounding said turntable at the sides to form a car body having a substantially solid top, and means for rotating the turntable while the car is within the tunnel kiln.



Method of and apparatus for glazing and decorating. CONRAD DRESSLER. U. S. 1,484,116, Feb. 19, 1924. In the method of firing and glazing ceramic ware of such character that gases and vapors are distilled therefrom during an initial stage of the glaze firing operation which detrimentally affect the glazing operation, if allowed to contact with the ware in a subsequent stage of the glazing operation, the improvement which consists in passing the ware continuously through an elongated kiln chamber so heated that the ware is gradually raised in temperature to the final temperature desired, restricting the flow longitudinally of the kiln chamber of the gases and vapors driven out of the ware and withdrawing said gases and vapors from the kiln chamber.



Method of and apparatus for bluing porcelain. CONRAD DRESSLER. U. S. 1,484,117, Feb. 19, 1924. In a muffle heated continuous kiln the combination with a kiln chamber and the muffle heating means therefor, of means for injecting fluid into a localized portion of the kiln chamber to make the atmosphere in that portion of the chamber either oxidizing or reducing as desired.



Continuous tunnel kiln. CONRAD DRESSLER. U. S. 1,484,118, Feb. 19, 1924. In a continuous tunnel kiln, the combination with a kiln chamber having side walls formed with burner chambers therein, of provisions for supplying air and fuel to said burner chambers, and nozzle members formed of carborundum and connecting said burner chambers to the interior of the kiln chamber.

Geology

Chinese kaolin for American potteries. ANON. *Far Eastern Rev.*, **18**, 511–4 (1922).—There are unworked deposits of good kaolin in Kwangtung and Manchuria. W. H. A. (*C. A.*)

Australian pottery clay. II. ANON. *Bull. Imp. Inst.*, **21**, 321–4(1923); cf. *ibid.*, *Imp. Inst.*, **19**, 465(1921).—Tests for the manuf. of semi-porcelain or impermeable stoneware were carried out with clay from Bendigo, Australia, contg. SiO_2 59.70, Al_2O_3 24.85, Fe_2O_3 1.45, TiO_2 nil, CaO nil, MgO 1.37, K_2O 2.30, Na_2O 1.66, loss on ignition 8.88%, in conjunction with feldspar contg. SiO_2 65.34, Al_2O_3 19.96, Fe_2O_3 0.47, TiO_2 nil, CaO nil, MgO 0.60, K_2O 7.96, Na_2O 4.44, loss on ignition 0.56%, and with massive, milky white quartz consisting of practically pure SiO_2. The results showed the clay to be quite suitable; but the working properties under industrial conditions should be detd. The compn. of the clay from this locality apparently varies considerably in different parts of the deposit. A. P.-C. (*C. A.*)

China clay. V. BODIN. *Science et industrie*, **7**, No. 108, 134–6(1923).—Comparison of English and French china clays and their respective methods of extn. and treatment. A. P.-C. (*C. A.*)

Chemistry and Physics

The preparation of artificial zeolites. PAUL EYMAEL. *Le Ciment.*, **29**, 4–6(1924).—There are a number of artificial products that have similar chem. properties to those

possessed by the natural zeolites, which are hydrous double silicates of alumina and a basic group. The indus. importance of the zeolites lies in the property that the basic group has of being easily displaced by another basic group. In water purification, by passing the water through a column of zeolite grains, the calcium in the water displaces the sodium group in the zeolite, thus softening the water. The lime in the zeolite is later removed by displacing it with a sodium group derived from a brine soln. Application has also been found in the extn. of alkalies from sugar soln., and in a number of chem. transformations. *Methods of prepn.* (*I.*) *Fused method.*—Such material as kaolin and quartz are fused with soda and feldspar, and the product leached with water. The granular residue when dried and ground to size is ready for use. "Permutit," $2SiO_2.Al_2O_3.Na_2O.+ 6H_2O$, is made in this manner. The German firm "Permutit A. G." has improved on the water washing process of the fused mass, which ordinarily breaks down some of the granules, for the alk. solns. obtained in the washing produce silicic acid by dissolving the granules, thus undermining the cohesion of the grains. This destruction has been prevented by adding silicic acid in the form of commercial sodium silicate, $1Na_2O.3–5SiO_2$, to combine with the alkali set free. *Wet methods.*—(1) The English Co. "Water Softeners Ltd." operates along the following lines: to a soln. of sodium sulphate, 2.5 kg. in 50 l. of water, are added with stirring 844 cc. of a soln. of sodium aluminate contg. 45.6 g. alumina, and 315 g. of a soln. of sodium silicate contg. 79 g. silica. The flocculent ppt. is decanted, washed with water and concd. by filter pressing. After drying and grinding the material is ready for use. (2) Another wet process is that of "The Refinite Co." A suitable clay contg. besides hydrated aluminosilicates, oxides of sodium or potassium, or their equiv. in calcium or magnesium, is made into a slip and treated with concd. sodium chloride soln. It is thus converted into an hydrated double silicate of aluminum and sodium. The mixt. is treated with excess sodium hydroxide, which dissolves free silica, sodium silicate and alumina, converts the acid double silicates into the sodium compds., and produces a fairly hard product easy to handle. After grinding the mass is crushed and dried for 48 hrs. at atmospheric temp., for 24 hr. at 100–200°, then calcined at 700°. On cooling, the product is allowed to become completely hydrated in a soln. of an alkali metal. (3) In the Brun process, a caustic soda soln. is added to a soln. of an aluminum salt, until the ppt. formed is just dissolved; then water sol. salts of sodium, as the phosphate, sulphate, chloride, are added. Finally a soln. of sodium silicate is added and the mixt. brought to a boil. The ppt. is washed, dried and calcined; it is also known as permutite. L. N.

The transverse strength of refractory clays. LARCHEVEQUE. *Brit. Clayworker*, **32**, 293(1924).—Tests were made on bars approximately 10 in. by $^4/_8$ in. by $^1/_2$ in. supported on knife edges 8 in. apart. It was found that: (1) Fire clays, china clay, porcelain bodies, etc., all bent much more in the raw state than in the fired state. A bar which had been fired 10 times, bent less than another which had only been fired once; (2) a clay mixed with grog bends more than the same clay mixed with sand; (3) the clay which bends least when mixed with grog also bends least when mixed with other non-plastic materials; (4) the increase in transverse strength produced by mixing Nemours sand with clay is significant; and (5) the cohesion of clays examined, both in the raw and fired state, was greater with mixtures of clay and sand than with plain clay. H. G. S.

Measurement of surface tensions. ALLAN FERGUSON. Fifth Report on Colloids, etc., *Brit. Assoc. Adv. Sci.*, **1923**, 1–12.—F. stresses the importance of surface tension and reviews recent work on the detn. of (1) *contact angles*, (2) *surface tension at liquid-gas interface*, (3) *interfacial tensions*. J. A. (*C. A.*)

Some artificial barium aluminium silicates. A. S. GINZBERG. *Coll. scientific papers dedicated to F. Y. Levinson-Lessing*, Petrograd, **1915**, 34 pp.; *Mineralog. Abstracts* **2**, 153.—The system $CaAl_2Si_2O_8$–$BaAl_2Si_2O_8$ is studied. Excess of $BaAl_2Si_2O_8$

crystallizes as uniaxial, + hexagonal plates, corresponding with nephelite. Mixed crystals with up to 20% $BaAl_2Si_2O_8$ were obtained. 2V diminishes from 80° for anorthite to 68° for the 20% mixed crystals, but the optical orientation is only slightly affected. E. F. H. (*C. A.*)

The influence of hydrogen peroxide on the precipitation of zinc salts with sodium metasilicate. A. H. ERDENBRECHER. *Z. anorg. allgem. Chem.*, **131**, 119–29(1923).—The ppts. produced by Zn salts and Na_2SiO_3 in the presence of H_2O_2 contain O in amts. which vary with the concn. of H_2O_2. These substances are not definite compds. but consist of mixts. of ZnO_2 and H_2SiO_3, together with some $ZnSiO_3$. With $ZnCO_3$, peroxides with a max. O content of 12.1% are formed. The $ZnSiO_3$ once formed is not changed by H_2O_2. The H_2O_2 procedure may be used as a means of detecting ZnO_2 in the presence of $ZnSiO_3$. J. A. A. (*C. A.*)

A note on the theory of specific heats. E. CSASZAR. *Z. Physik*, **19**, 213–20 (1923).—C. summarizes the results of Debye. A new formula for the sp. heats of solid substances is derived, departing from the classical theory in that it is assumed that a crit. energy limit exists, below which the atom gives up energy discontinuously, and above which classical continuity exists. This leads to a finite series for sp. heats, instead of the infinite series of Debye's formula. Sp. heats calcd. with this formula upon Ag and Cu are compared with those calcd. by Debye's method and with exptl. results. There is good agreement. J. H. P. (*C. A.*)

Compressibility of minerals and rocks at high pressures. L. H. ADAMS AND E. D. WILLIAMSON. *J. Franklin Inst.*, **195**, 475–529(1923).—Detn. was made of the compressibility of a no. of minerals and igneous rocks under hydrostatic pressures as high as 12,000 megabars; the specimen was completely surrounded by kerosene, and subjected to pressure in a thick-walled steel bomb. The compressibility usually decreased slightly as the pressure was increased; although the change was so small for the less compressible minerals that it escaped detection. In certain expts., porous rocks were covered with a thin jacket of pure Sn to prevent the kerosene from entering the pores; in these expts., at pressures above 2000 megabars, porosity had little effect on the compressibility. The more porous rocks, however, may show an abnormally high compressibility at low pressures. Except for very low pressures, the compressibility of a holocrystalline rock may be calcd. from the known compressibilities of its constituent minerals. The compressibility usually increases with increasing basicity. Of the igneous rocks, quartz and metallic Fe are the two extremes of compressibility. In any given class of rocks, variation in compressibility at high pressures is small and due almost entirely to variation in compn., while variation at low pressures is much larger and depends chiefly on the degree of compactness. At 10,000 megabars the compressibility per megabar is approx. 1.9×10^{-6} for a typical granite and 1.2×10^{-6} for a typical gabbro. At this pressure, the rigidity of granite is 0.3×10^6 megabars, gabbro 0.5×10^6, dunite 0.6×10^6; the rigidity of the earth as a whole probably is approx. 0.9×10^6, a value higher than that of the most rigid silicate rock, this being doubtless produced by the pressure of a few hundred miles of rock on basic or ultrabasic rock. With increasing basicity, the velocity of the longitudinal vibrations, which are transmitted through the earth, increases from 5.6 km. per sec. in granite to 7.4 km. per sec. in dunite. Their initial velocity is slightly above 7 km. per sec. corresponding to a gabbro or a pyroxenite and showing the presence of basic or ultra-basic material at a comparatively small distance beneath the surface of the earth. J. S. H. (*C. A.*)

Properties of powders. The variation of pressure with the depth in columns of powders. J. H. SHARBY AND J. C. EVANS. *Trans. of Faraday Soc.*, **1923**.—Measurements of the (average) vertical pressure pa at various depths x in columns of lead shot and of powder indicate exponential increase of p with x. The absolute value of the

pressure appears to be dependent on the state of packing of the column and the resulting shape of the equal pressure surfaces; if so the observations supply grounds for inferring that a difference in packing sets in from the start, it being possible, after taking the first pressure reading to predict fairly accurately the value of the maximum pressure. The general form of the pressure-depth curve agrees well with the equation pa equals $pm(1-Ce^{-kz})$ in which pm is the maximum pressure and C and k are constants. The apparatus used was described and results are given which check closely with the calculated values. F. C. F.

PATENTS

Process of separating the constituents of mineral silicates. JOHN B. LARUE and SHERMAN W. SCOFIELD. U. S. 1,483,627, Feb. 26, 1924. In the process of converting potash-feldspar into potassium silicate and aluminate by means of converting crystalline feldspar into amorphous feldspar and heating a mixture of said amorphous feldspar and a solution of caustic potash in a closed vessel, the step of converting silicic acid into silica which consists in continuing the heating until the moisture is absorbed by the crystalline mass, resulting in a material reduction of the pressure and a material increase in the temperature.

Manufacture of chrome alum. PETER HASENCLEVER. U. S. 1,486,961, Mar. 18, 1924. The process for manufacturing chrome alum which consists in dissolving ferrochrome in a non-oxidizing mineral acid capable of dissolving ferrochrome, precipitating from the solution chromium hydroxide, the iron remaining dissolved, separating the chromium hydroxide from the liquid, dissolving the chromium hydroxide in sulphuric acid, adding potassium sulphate and crystallizing.

General

The packing of earthen ware. C. M. BONNELL, JR. *China, Glass and Lamps,* **43** [26], 11(1924).—Breakage in pottery during shipment is very often due to the method of packing. Efforts to improve packing have generally been rather unsuccessful. The U. S. Potters Assoc. granted 25% more wages to do this, but without effect. Piece work was tried, but was even worse. An example was given to show the cost of hurrying up. A large mail order house uses a conveyor system. Frequent thorough inspection has made their packing problem a minor one. They also use excelsior instead of straw. It is slower to pack, so the packers object when on a piece work wage. However, excelsior goes further than straw, which helps to reduce the ultimate price of the excelsior. Very often a few poor workmen give the rest of them a bad reputation, but the good ones do not feel that they can conscientiously report them. Figures are given showing the effect of variation in the moisture content of the staves used for barrels and indicating that proper seasoning is necessary. Wet packing material, either by sprinkling to keep down dust, or when wet after packing, is a very bad practice as the material swells and then shrinks away from the ware. F. C. F.

Electrical conductivity of solid and fused silicates. C. DOELTER. *Rec. Trav. chim.*, **42,** 720–32(1923).—A few silicates conduct at ordinary temp. Results on condy. and polarization of fused silicates are given. Electrolytic condy. is often present, even in solids. Nearly all silicates conduct at 1000°C. W. M. C.

Franco-Belgian Association for testing materials. Session of June 23, 1923. H. C. *Rev. Mat. Constr. Trav. Pub.*, **166,** 165–7(1923).—Petrographic study of refractory clays, clays for cements, and limestones, Bied and Jourdain. Clays after drying were heated slowly between 30° and 40° in a tinned iron crucible with a mixture of Canada balsam and benzene for many hours until hardened. The hard mass is then cut up into thin sections, polished and mounted on glass slides, according to the established

technique for obtaining petrographic rock sections. Clays can be grouped as follows: cryst. kaolinite and halloysite, amorphous or colloidal, allophane and collyrite. L. N.

A new mechanical fuel feeder. ANON. *Brit. Clayworker*, **32**, 312(1924).—Illustrations are shown of a new stoking appliance for feeding coal into a Hoffmann kiln. H. G. S.

Producer-gas and gas-producer practice. VII. R. V. WHEELER. *Fuel*, **2**, 369–72 (1923); cf. *C. A.*, **18**, 458.—The subject is concluded under the following headings: efficiency of a gas plant, gross and net calorific values, efficiency trials, radiation losses, losses due to sensible heat of the product, losses due to unburned fuel and the choice of fuel for gas producers. C. C. D. (*C. A.*)

Electric furnace types surveyed. L. W. EGAN. *Iron Age*, **112**, 1283–6(1923).—Discussion of the advantages and disadvantages of the arc, resistance, and induction furnaces for foundry use. Elec. furnaces out-class the best combustion furnace practice except in installation cost. The arc type is most rapid in action, has largest capacity per unit; the muffled arc is a large heat source at comparatively low temps.; Baily resistance furnace gives greater metal temp. uniformity; Ajax induction has low power cost and low metal cost. Induction furnaces are ideal electrothermic units, but are not suitable for steel. The resistance furnace excels with dirty charges. Melts can be made better and cheaper in resistance furnaces than in combustion furnaces. C. L. M. (*C. A.*)

Advances in ceramics. W. FUNK. *Chem.-Ztg.*, **47**, 673–5, 701–3, 718–9, 734–6, 742–4(1923). E. J. C. (*C. A.*)

Ceramic industries in England. A. S. W. ODELBERG. *Svensk. Kem. Tids.*, **35**, 247–66(1923).—A descriptive and historical article. A. R. R. (*C. A.*)

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Vol. 3 **May, 1924** **No. 5**

EDITORIAL

COÖRDINATING RESEARCH AND TECHNICAL INFORMATION WITH PLANT CONTROL[1]

By J. A. Jeffery

Introduction

No industry can expect to enjoy prosperity and maintain supremacy over a period of years that depends on patents or secret formulae.[2] A wide awake competitor with research facilities will discover new and better ways of accomplishing the same results within a more or less limited period. A manufacturing enterprise must advance scientifically, but this cannot be accomplished without proper organization and equipment.

As a nation we are restless and ever anxious to work out new methods, in fact it is almost a national vice to discard the old and experiment with new ideas and devices. To a great degree our patent laws are responsible for this situation as they encourage inventions through profits that are expected to accrue from the monopoly they intended to create over a period of years; but there is a deeper instinct involved, that of industrial progress which is born in us.

It is unfortunate that we are so prone to take short cuts instead of methodically searching the literature that is so abundantly available.

[1] Presented at the Atlantic City Meeting, Feb., 1924. (General Session.)

[2] Italic is by the editor.

One of the saddest things we can imagine is to find a man laboring for months, or years, over a problem that has been worked out long before his time and which even a limited survey of text would have disclosed to him. The average man seems possessed with the thought that a clever idea he may have conceived is new and worthy of protection through patents, and it is to be regretted that so many Patent Attorneys encourage such clients and that the Patent Office in turn issues such an endless chain of worthless patents. However, this difficulty is not confined to the individual, for many industrial organizations are spending great sums of money and valuable time in just such useless efforts through lack of a suitable research and engineering organization.

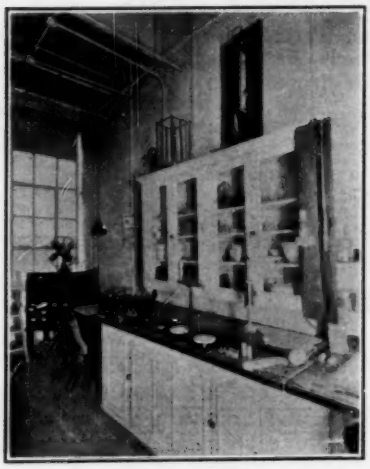

FIG. 1.—Ceramic laboratory. Preliminary tests are made here on all raw materials before accepting them.

It is well to lay special stress on the fact that *pure Research cannot be well conducted in a manufacturing enterprise by a single individual.* As a rule the results of this work would be almost useless to the business itself owing to the fact that a man mentally equipped to delve deep into nature's secrets, rarely has the engineering genius to put his discovery into workable form. Therefore, we should have in addition to the scientist or research worker, an engineering force capable of working out the practical application of the discovery or invention.

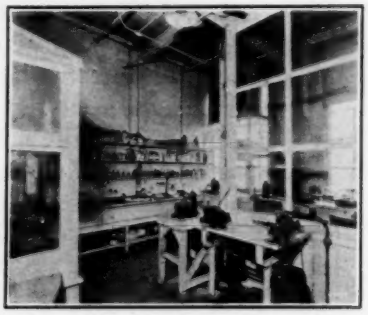

FIG. 2.—Chemical laboratory. All materials are analyzed at intervals. Every carload of some materials is analyzed.

Research Organization

In coördinating the research with production it is essential to have the organization so arranged, that coöperation is maintained. There must be someone in the personnel who is experienced in both the production and experimental work to such an extent that success will result when experiments finally become production problems. Here is one place particularly where a special department, such a one as our Process Laboratory which will be described later, plays an important part.

A well-planned research division in any industry includes first of all of course an efficient well trained personnel, whose activities are guided by a research director who *must* be a man of broad training and experience. And for successful research and plant control the necessary laboratories and departments must be available, and in our work we have found the following to be indispensable:

1—Ceramic Laboratory
2—Chemical Laboratory
3—Electrical Laboratory
4—Mechanical Laboratory
5—Testing Laboratory
6—Petrographic Laboratory
7—Library
8—Record and File Clerk
9—Legal Department

Conditions which arise in coördinating research and technical information with plant control are so numerous that it is very difficult to cover the entire field in a general way. Bearing this in mind it is the writer's

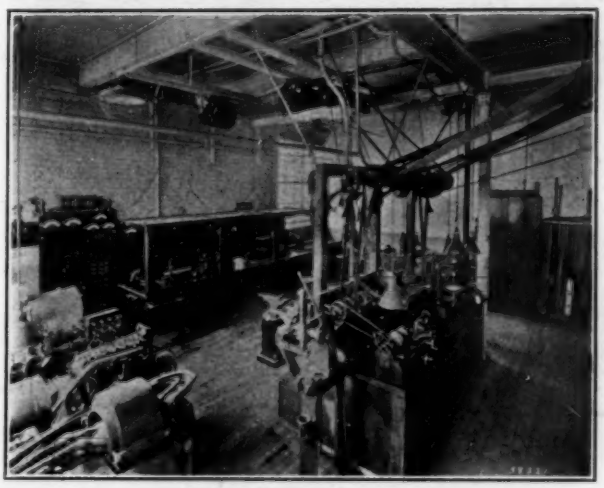

FIG. 3.—Electrical laboratory. Equipped for testing spark plugs, calibration of thermocouples and building of small electrical equipment if special.

opinion that he can accomplish more by presenting the details which have arisen in a ceramic plant. This is particularly so in this case as it is the ceramic industry that we desire to deal with.

Routing of the Work

All ideas, conceptions, or requests for information originating in the factory or within the Research Division itself, must be referred to the Director and by him assigned to the laboratory or individual best equipped to handle this problem.

ORIGIN OF THE PROBLEMS

Quite frequently the problem is so complex that several divisions must be called upon to solve certain parts of it, for instance—quite frequently it is discovered through the Sales Organization that a competitor has developed some radical improvement. Let us suppose this to be a porcelain article that is subject to tensile stresses. How then should this be handled?

THROUGH THE RESEARCH LABORATORIES

Experience has long since taught us that the microscope should be first employed and a careful examination made to disclose any new mineral that might have been used in the body, as well as to indicate the character of the porcelain as to grain fineness; degree of solution of the silicates such as quartz; the quantity and character of the crystal development; and the probable temperature of burning.

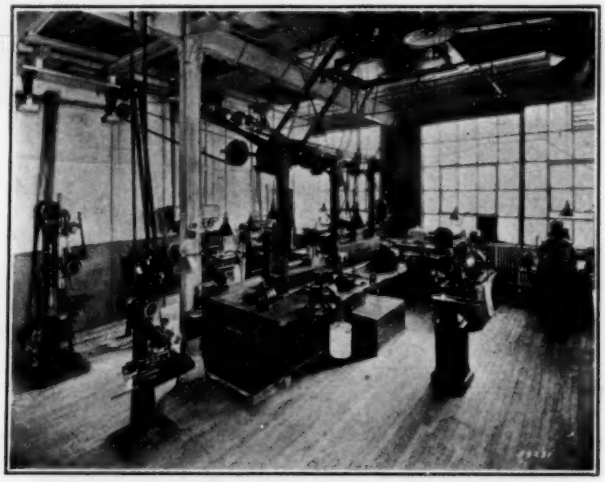

FIG. 4.—Mechanical laboratory. Many special machines and instruments are made here.

The Petrographer would then report his findings to the Director, and in turn the Chemical Laboratory would be called upon to make a complete analysis; then from its results, the Ceramic Laboratory would be called upon to reproduce the body or porcelain of like character and improve upon it if possible.

Obviously, if the porcelain is to be fabricated in the form of an insulator we must now call upon the Mechanical and Electrical Laboratories to make tensile and shock tests on the finished article, as well as to establish the electrical values at atmospheric and elevated temperatures.

In an industry of considerable magnitude it is evident that a large staff is necessary to carry on consistent research and at the same time take care

of manufacturing problems as they arise. As a matter of fact if a highly specialized product is made, not only careful physical tests of raw materials are necessary but accurate chemical analysis of nearly all raw materials is absolutely essential. Not less than two men should be steadily employed in the work of checking raw materials.

THE PROCESS LABORATORY

Let us now assume that it is desirable to put a new body or formula into production. At first thought this seems a simple matter, but it frequently takes at least a year to iron out many of the problems that arise when we attempt operations on a large scale. In our industry a multiplicity of troubles arise from the complex nature and properties of the matter we know as clay and the peculiar reactions that take place in burning.

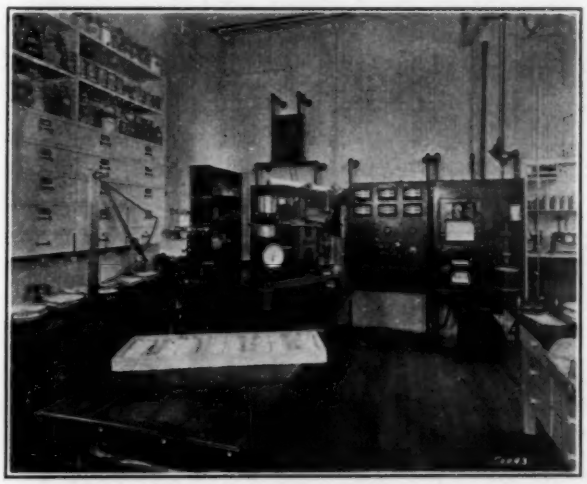

Fig. 5.—Testing laboratory. All plant control tests on production ware are made here, such as impact, thermal shock, electrical resistivity at increased temperatures and the like.

The difficulties involved in introducing a new body into full production in the factory led us to equip what is known as a Process Laboratory, the function of which is to prepare and fabricate the new composition on a small production scale. As a matter of fact this laboratory is a small yet complete manufacturing plant itself, equipped with full-sized units which are exact duplicates of the factory equipment including mills, pugs, forming machines, glazing machines, kilns, etc. Obviously the new body can be then produced in considerable quantity over a period of time sufficient to permit accurate study of its behavior and the effect of different lots of material, as well as its behavior over the full range of burning temperatures.

During this period accurate records are kept of the speed of operation and the percentage of good ware produced, as well as average mechanical and electrical values. If possible, the body is adjusted to give the same shrinkage as the body in production in the factory. If this is not possible,

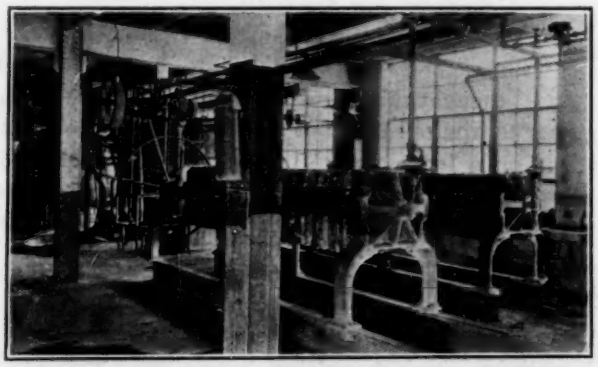

FIG. 6*a*.—Process laboratory slip house containing six-foot pebble mill, blunger, lawn, magnetic separator, filter presses, etc.

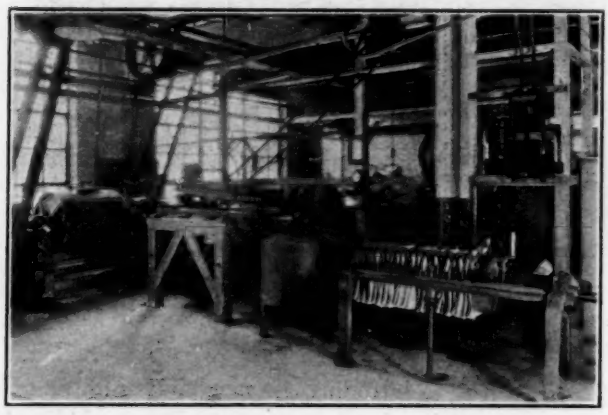

FIG. 6*b*.—Process laboratory slip house containing thirty-inch pebble mill and other necessary equipment of proportionate size.

then all dimensions are accurately worked out so that the equipment can be altered to conform to the new shrinkages.

In the usual order of events radical composition changes are not frequently necessary and the continuous employment of a trained Process Laboratory force would not be warranted. However, there is another and more important function performed by this department.

FUNCTION OF PROCESS LABORATORY IN QUALITY CONTROL

In the manufacturing of a highly specialized product it is essential to rigidly control the properties of the porcelain body and this is best accomplished by preparing the body in 40,000 lb. dry-weight batches which are stored in separate masses after weighing, milling, and filterpressing. Within a day or so after the body has reached the aging cellar a few hundred pounds is

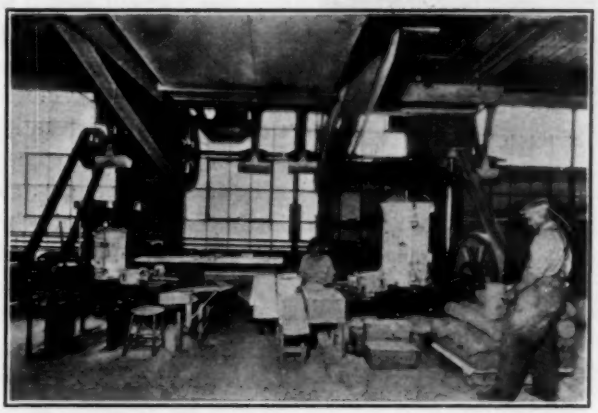

FIG. 7.—Process laboratory containing one full production size pug mill for blanks and one-half size.

withdrawn and taken to the Process Laboratory where it is pugged, dried, formed, glazed and placed in specially marked saggers which are burned through the tunnel kiln, then returned to the Process Laboratory for final inspection and tests. If this lot of porcelains passes all standard tests, the 40,000 lb. batch from which they were made is released to the Production Division; but close check is advisable and if practical, each batch should be traced through the Production Division and at least one piece of the finished product, and more if the article manufactured is small, should be selected from each kiln car or sagger and subjected to final tests. The final tests should in no case be trusted to the Production Division, for as a rule the latter is only seriously concerned with quantity and can hardly be expected to watch the quality.

FIG. 8.—Process laboratory. Turning department equipped with six standard sized machines and independent means for catching the body dust.

Importance of Patent Protection

One of the most important responsibilities of the Director of Research in a modern industry is to protect the work of his division through patents. Too much emphasis cannot be placed on the necessity of great care in selecting proper legal advice. A Patent Attorney should preferably be selected who has had not only a wide experience but one who has specialized in the particular industry with which we are concerned. To be competent to handle the legal end of such an industry as ours, he should have a fair knowledge of engineering and chemistry and must familiarize himself with much of the ceramic literature and foreign patent art.

FIG. 9.—Process laboratory. Automatic glaze spraying machine. One operator puts the unglazed green cores on the revolving spindles. These pass by the atomizers and are coated with glaze, removed by the other operators and placed in saggers.

If proper steps are not taken to protect inventions that originate in the Research Division or that are worked out from suggestions from the factory, it would be difficult to show that any results have accrued from the activities of this department.

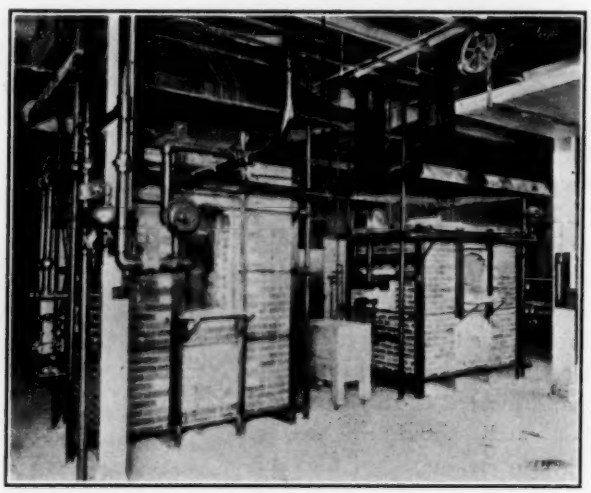

FIG. 10.—Process laboratory kilns. One will hold 1200 cores, the other half that amount. Ordinarily all tests are put through the production kilns.

Secured Assurance of Benefit from Acquired Knowledge of Employees

As a rule the men who are employed to carry on the work in the Research Laboratory are selected for their particular ability or education. Generally they take the position expecting to seek a better one after having had the benefit of practical training and experience. The realization of this often is a severe disappointment to the employer, but on the other hand the type of man that is valuable in research work and to his department is almost certain to be ambitious and restless for further experience or advancement. Obviously, then the benefit of their work would be lost were they to leave the organization to take a somewhat similar position with a competitor. It is easy to see how the results of much of their work would then pass directly into the hands of the new employer who is probably provided with means and equipment to reap the benefit of their work to the detriment of the concern that had made their former activities possible.

FIG. 11.—Process laboratory dryer equipped with automatic control.

Protection against Unfair Competition

It is a well known fact that there are many manufacturers who do not hesitate to prey upon and pirate ideas that are the property of others, actually believing they have shown keen business ability in so doing. It is fortunate, however, that the courts now frown on such tactics and it is becoming less difficult to establish the fact of unfair competition or intent to defraud. Patents, however, are not our only protection and the possibility of even more adequate protection through design patents and trade marks should not be overlooked. Infringement of patents is sometimes difficult to establish, whereas, unfair competition or intent to defraud the public is much more easily proven and in some instances the Post Office Department can be called upon to punish the offender and thus protect both the manufacturer and the public.

FIG. 12.—Plant control tests. The impact test is made by dropping a weight a definite distance onto the end of a porcelain core held horizontally in a firm position.

PATENT RIGHTS OF EMPLOYER AND EMPLOYEE

Before a man is employed or added to the staff of the Research or Engineering Division of a modern industry, the importance of protection should be explained to him and he should be required to sign a suitable and fair agreement to convey the title of all inventions to the Company that employed him, thereby saving both parties much annoyance and expense as well as endless argument, should a dispute ever arise. It is not pleasant to have legal actions arise from lack of a clear understanding of a man's duties and the purpose of his employment. It is easy to assume that he is attached to the Research Division for the purpose of improving the product, and equally reasonable to assume that inventions thus created or conceived belong to the employer, but it is another thing to prove this if suitable documentary evidence is lacking. In the case of a disgruntled employee it is surprising how he will try to evade responsibility and claim that an invention or conception is his property and only shop rights belong to the employer.

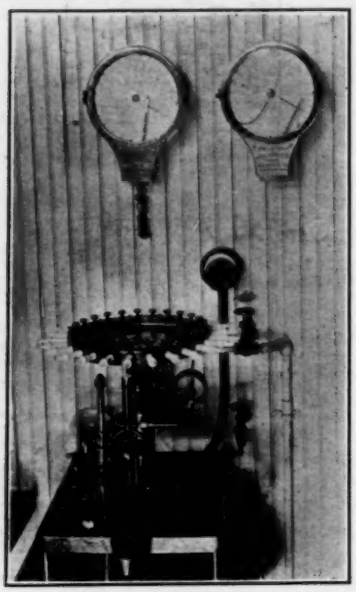

FIG. 13.—Plant control tests. The heat test consists in suddenly exposing the end of a cool porcelain to the flame of a meeker burner and leaving it there for 60 seconds. All conditions as to temperature, time, etc., are accurately controlled.

The writer sincerely believes that these relations should be thoroughly understood and the agreement between the employer and laboratory worker be complete and fair to both, otherwise distressing arguments are certain to arise resulting in a direct loss to both parties, as cordial relationship should continue to exist after a man seeks a new position. From time to time an exchange of ideas may be of great benefit to both parties.

Duty of Research Director to Publish

There is another angle that should receive serious consideration for the benefit of the industries at large. *Until we have adequately organized and financed Research Bureaus that are supported by such industries as ours, I believe it to be the duty of the Director of Research in an industry to publish at proper intervals the results of research that cannot be considered an essential shop secret.* The publication of such matter through papers presented

before the societies representative of the industry in question, makes this information available to others who might otherwise spend much time and effort covering the same field. A good example might be cited as follows:

In the development of 18 and 19 cone bodies no small part of the problem was to find suitable kiln refractories and containers or saggers. Obviously, in this development many features were accomplished that will result in great economies in the 11-12-13 cone field, and the publication of such developments cannot injure the interests of investigators.

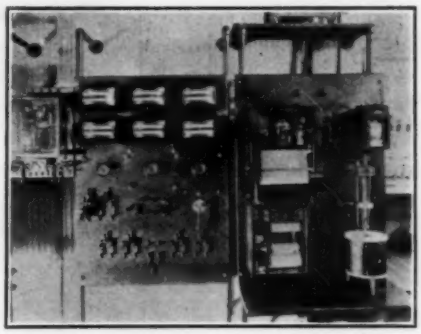

FIG. 14.—Plant control tests. The hot dielectric test determines the electrical leakage of the porcelain at increased temperature as well as the temperature at which the final failure occurs. All conditions must be constant and accurately controlled.

Less Secrecy and Greater Exchange of Information

In closing, the writer desires to plead for less secrecy and greater exchange of information and ideas. With a well organized research staff and modern laboratory equipment there is little protection possible through secret formulae. With an experienced petrographer, a capable chemist, and a ceramic engineer any porcelain article now manufactured can be duplicated if desired, hence there is little to be gained by secretiveness. No fair-minded man can expect to receive information if he is not willing to reciprocate.

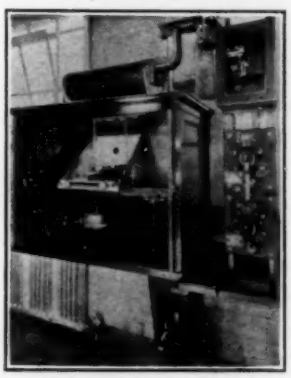

FIG. 15.—Plant control tests. Equipment built in our own laboratories and designed to determine thermal expansions up to 1100°C.

Value of Broad Training

The Schools and Colleges should encourage the young ceramic engineer to gain the broadest possible experience along other lines of engineering, particularly those applied in our ordinary manufacturing plants. There is an old saying that the most uncommon thing in the world is common sense, but we can truthfully state that men capable of assuming the duties of Research Director or Plant Manager in the modern progressive ceramic industry are as scarce as the proverbial

"hen's tooth." There is a fine field for rapid advance with unusual monetary compensation for the men with wide practical engineering experience and good knowledge of works control.

THE CHAMPION PORCELAIN CO.
DETROIT, MICH.

PAPERS AND DISCUSSIONS

ECONOMIC FACTORS THAT MAKE RESEARCH IN INDUSTRY IMPORTANT[1]

By William R. Mattson

What I wish to bring to the members of the American Ceramic Society is the relationship of general business to research and also a few points as to just how we can tie up the ceramic industry to general business. The objects of this Society and the objects of the organization which I represent are more or less the same; that is, you are all interested in the improvement of industry and the improvement of business, and we, by our studies of economic conditions, wish to help business in a general way and industries in a specific way as far as we can. I first want to discuss a few general problems and then something of a more specific nature.

American industry has developed to such an extent that an analysis of even surface conditions shows the importance of research in business.

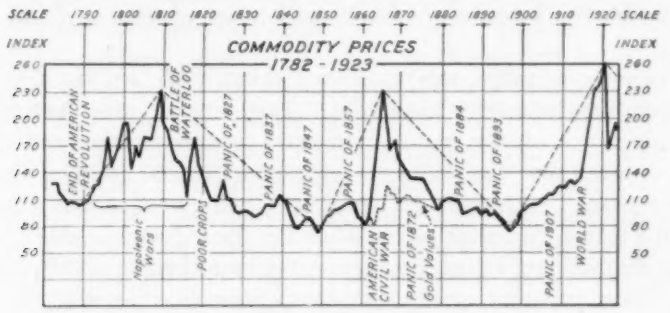

Fig. 1.

Fundamental changes during the past five years have developed numerous economic factors that indicate that business is in that stage where research is of the utmost importance.

Business is still experiencing the effects of those years of expansion and inflation, during and immediately after the war. Although many manufacturers and business men feel that we are now back to normal, you will note numerous changes during the next few years that will be directly attributable to this inflationary period.

Take, for example, the matter of commodity prices. Over a period of approximately 150 years, commodity prices have experienced three major periods of inflation and the same number of depressions (see Fig. 1). It is interesting to note that the increases started from fifteen to twenty years before the peak was reached. Each peak price was reached shortly after a war. Then followed a long period of commodity price decline usually

[1] Presented at the Atlantic City Meeting, Feb., 1924. (General Session.)

starting with a very decided reaction. We are all familiar with the trend of commodity prices since 1920. Although I do not mean to state that present business conditions are directly comparable to those following the Civil War, it is interesting to note that commodity prices have declined about the same amount since 1920 as they did during the corresponding length of time following the Civil War. Now, the indications are that the long pull trend of commodity prices is downward. Of course, we shall note various fluctuations and an upward trend from time to time such as occurred during the winter and early part of 1923. Certain economists believe that we have reached a level which will be well maintained for some time to come. No matter which group is correct, the important point is that we are not facing a long trend rising commodity market.

Such a situation as this means that certain methods of business which prevailed during the period from 1910 to 1919 will not be successful during the next four or five years. A rising commodity market favors the business man who is a speculator. A declining market favors the conservative man who studies business conditions and takes advantage of the general trend.

The rising commodity market from 1900 to 1920 had the direct effect of stimulating industrial expansion. Furthermore, war demands were such that many of our major industries became over-expanded. This factor, as you know, has seriously curtailed industrial building during the past four years. Although this handicap is being overcome in many lines, it is still a factor that must be considered in the industrial outlook. Probably the shipbuilding industry is the outstanding example of this condition.

This heavy capacity means that competition is unusually active. To meet this situation, manufacturers must keep their costs and prices low in order to maintain a good volume of sales. Without a doubt, the reduction of costs demands effective research of a technical and economic nature. The study of efficient distribution is still in its infancy and considerable research work must be done in this field by successful business men during the next few years.

The cost of production in many lines has been steadily declining. Intensive research work has been done in this field. The cost of distribution on the other hand, has been steadily increasing. It is much easier to manufacture goods at the present time than it is to dispose of them. The most successful manufacturer or distributor during the next few years will be the one who applies research work to his problem of distribution as well as the problem of production. In practically all industries, costs can be cut by better methods of distribution.

The business outlook for the rest of this year also indicates that real intensive economic research will be necessary in order to maintain a reasonable amount of profit. We are now in what might be termed "a normal

zone of business." There is little probability that we shall experience any radical fluctuations such as have been noted within the past five years. There are numerous bullish factors that might be mentioned which would indicate that the outlook for business this year is especially good. Transportation has been active and the railroads are in fairly good condition. Employment was heavy throughout the greater part of 1923, wages were high, and the spending power of the public is now good. The 1923 income of the farmers was better than in either of the two preceding years. Money rates are low. Building activity has been large and the indications are that 1924 will be another fair building year.

Offsetting these factors are certain bearish conditions. Expansion has been unusually rapid in many industries and the probability is that some of them will be forced to curtail production this year. Prices are still somewhat out of alignment. In many cases, goods are so high that buying is very conservative, with no likelihood of an improvement until lower levels are reached. Furthermore, the foreign situation is of considerable importance, especially in such lines as the ceramic industries. The general outlook for individual industries depends on the extent to which those industries are affected by the economic factors just mentioned.

Now just how do these general statements apply to the ceramic industries? Just why is it necessary for manufacturers in these lines to pay particular attention to research work? In the first place, the general trend of the ceramic industries is comparable to the broad changes in business. A direct comparison of the total value of products of the various branches of the ceramic industries with the Babsonchart clearly shows the close relationship (see Fig. 2). This chart also shows that a further readjustment in business would undoubtedly mean further changes in the ceramic industries. Consequently, the manufacturers in these lines should first pay special attention to the trend of general business in estimating what is ahead for their business.

On the basis that the long pull trend of commodity prices is downward, it is evident that ceramic manufacturers must study the methods of reducing costs or else have their profits reduced. In meeting this condition, these studies should develop along two main lines. In the first place, continued research should be made for improvement in manufacture. An analysis of these problems comes under the direction of the industrial engineer. In the second place, special attention should be paid to problems which are exterior to the immediate details of the business but which have a decided effect on the profits of the concern. These include a study of general business conditions and the factors in general business which are directly applicable to the ceramic industries. The trend of demand, prices, competition within the industry, and competition with foreign manufacturers are all of extreme importance.

A study of demand in this industry shows that the trend should be more or less continually upward. The products of the ceramic industries are of universal use and there is no reason why the total consumption should not increase at least as fast as the population. Certain lines which are directly used in building, of course, will follow the fluctuations in that industry. The long pull trend, however, should be upward. Such yearly fluctuations as will occur in demand will probably be directly attributable to and comparable with the changes in general business.

A detailed analysis of the industry shows that competition among domestic manufacturers is becoming especially keen. This industry has probably reached its saturation point and there is little doubt that capacity is more than necessary to supply a normal demand. Statistics for the clay products industry reported by the Census of Manufactures show that the number of concerns is tending to decrease. Twenty years ago, there were 5,500 establishments reporting while the value of products was given

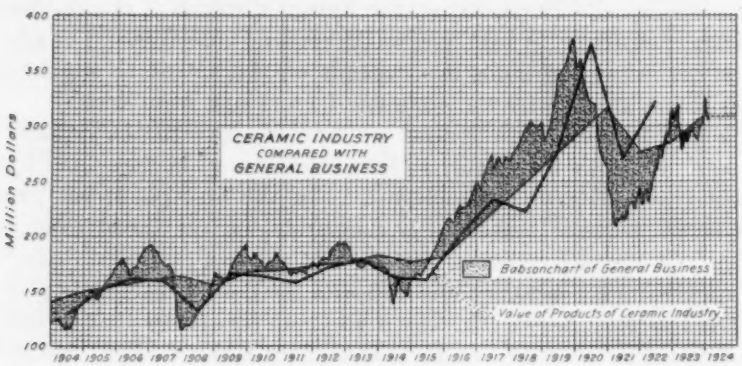

FIG. 2.

as $135,000,000. Each census year showed a decline so that in 1921 there were 2,150 establishments reporting but the value of products had increased to over $278,500,000. The number of wage-workers has decreased from 118,000 in 1904 to 97,000 in 1921. It is interesting to note that in 1909, there were approximately 133,000 workers in the industry. In 1919, there were only about 105,000.

In the various branches of the industry, we also note a decline in establishments. In 1914, there were 350 pottery concerns reporting, whereas in 1921, these had decreased to about 270. The manufacturers of brick, tile and terra cotta in 1914 numbered 3,239 and these had decreased to 1,880 in 1921. The number of workers also declined. These changes are probably due to the gradual elimination of the weaker concerns, the invention of labor-saving machinery and also foreign competition. We see no reason why the trend indicated during those years will not continue.

At the present time, probably the most important external problem in the industry is foreign competition. This factor was of importance before the war and may have been one of the principal reasons for the decrease in the number of concerns from 1900 to 1914. With the curtailment of imports during war years, the industry was materially increased. The increase in the value of products in the clay products industry during the five-year period 1909 to 1914 was from $168,800,000 to $172,800,000, an increase of only $4,000,000. In 1919, however, the value of products amounted to $283,300,000 or an increase of nearly $111,000,000 from 1914 to 1919. We realize that a certain amount of this was due to price inflation but the actual volume of products also undoubtedly showed a very heavy increase. However, throughout the five-year period, the number of concerns in the industry showed the same tendency to decrease which was noted throughout the pre-war years.

A study of import statistics shows the trend of foreign competition. Imports of clay products were decidedly restricted during the war years but since then a steady increase has been noted. In the case of pottery, for example, the value of pre-war imports amounted to approximately $10,000,000 annually. This decreased to about $5,600,000 in 1916 but since then has been steadily increasing. In 1920, the imports of pottery amounted to $10,000,000 and in 1923, the imports were well over $16,000,000. The increase has been especially noticeable in decorated chinaware and decorated earthenware. In the former case, the value of imports has increased from about $3,000,000 in 1916 to about $7,500,000 in 1923. Decorated earthenware increased in this period from $1,700,000 to nearly $4,000,000. The indications are that this upward trend will be continued despite the present tariff regulations.

Special research work will have to be done to meet this foreign competition. It is doubtful whether producers in this country can compete on labor costs with those abroad. Living conditions are different and unit wages are very much less in the principal ceramic producing countries in Europe. Consequently, it seems that the American producers must meet this situation by the production of more efficient machinery. They must also improve the present methods of distribution in the domestic and foreign markets. The indications are that the foreign producers will be able to win out on the grade of ceramic products in which labor cost is the most important factor. Manufacturers of machine-made grades should be able to build up an American market in which they will be able to compete successfully with foreign producers.

The tendency in price will be downward. Statistical data as to prices in the industry are very incomplete. However, government figures show that certain grades of chinaware are now over 125% above the pre-war level. The price index of all commodities is about 60% above the 1913

base. Advertising should be increased and should be more efficient. Special study should be made of transportation costs which is a very important factor in the industry. Furthermore, better trade information should be available. Data pertaining to the fundamental factors of the industry are very incomplete. This may be due to the complexity and variety of the products of the industry. Possibly a decided saving could be made by a better standardization of products. Many of our important industries are now devoting special research work to the elimination of unnecessary and unprofitable lines. Numerous other factors might be mentioned but the indications are that most of these would pertain to the problems of distribution.

The ceramic industries are essential to the United States and, if properly handled, should be able to successfully meet their foreign competitors. There are, however, numerous problems which must be studied. The future success of the industry depends on the solution of these questions. The best method, in fact, the only method of meeting these conditions is efficient research. This must be devoted not only to the detailed problems of production, but also to the many and complex problems of distribution. The general outlook for the industry indicates that the manufacturer who follows these lines should be prosperous and enjoy good business despite the numerous problems that are ahead.

Babson Statistical Organization
Wellesley Hills, Mass.

THE INVESTIGATION OF TERRA COTTA WORK AT THE BUREAU OF STANDARDS[1]

By Eckardt V. Eskesen

ABSTRACT

Research is being made covering failures due to popping, grazing and spalling. This work has been going on for nine years, first under the direction of Professor Bleininger, and later on under Professor Bates.

One or two fellow Ceramic Engineers have been constantly engaged in this work. Various tests, such as freezing and thawing have been conducted for the purpose of testing different clay bodies and glazes submitted by the manufacturers.

I have been asked to say a few words in regard to the investigation of terra cotta work now going on at the Bureau of Standards at Washington. As I am not a ceramist myself, I will not be able to go into details or enlarge on the methods employed and the different tests conducted at the Bureau of Standards. Others present here may be able to do this much better. I can only talk about the subject in a general way and try to outline to you the benefit which our industry may in time derive from this investigation.

[1] Presented at the Atlantic City Meeting, Feb., 1924. (General Session.)

The work at the Bureau of Standards has been carried on for some eight or nine years at some expense to the Society, and at great sacrifice to the heads of the Bureau, who have in every way possible accommodated and assisted us in our work, and have given much time and study to directing this research work. I wish to say here that the Bureau of Standards is greatly interested in our problems and is enthusiastic about carrying out this research work to a final conclusion.

In every industry there are problems and troubles which are constantly popping up. Nothing is perfect. We must progress and while we are progressing we come in contact with new difficulties. New machinery and new methods have changed conditions and it is no more the old way of production.

So in the terra cotta industry—a comparatively new industry in this country. The pioneers who first opened up the road and introduced terra cotta to the American architects were not confronted with the problems which confront us today. They had other problems naturally, such as getting a suitable clay, uniformity in colors, etc.

At that period the building construction consisted of solid masonry. The terra cotta was carried in the wall on its own bond, very seldom any iron or other material being used for support. There were no failures of terra cotta then. You can go out and look at these jobs produced thirty or thirty-five years ago. Some of these buildings are still standing and the terra cotta looks as good as new, or as if it were made yesterday.

This was before the period when sky-scrapers came into being. With the sky-scraper also came into use the iron and steel construction, and later on the concrete construction; so today we have what is called modern American building construction, meaning that all the construction going on today outside of residences and small dwellings, is erected in concrete or iron and steel.

With the introduction of the sky-scraper and the concrete building, came before us the problem of how to adapt our material to the changed conditions; how to support a load of terra cotta, which now under the changed conditions, is used simply as a veneer on the front of the building, and how to hang the projecting courses, and tie down the tiers of ashlar work.

Before the period mentioned by me the range of colors put into the market by terra cotta manufacturers had been very limited. To start with in this Country the colors only consisted of red or terra cotta colors; then came a period where the cream color or fire flash colors came into use; later on nothing but gray colors were used, and with very few variations away from that rule. At this last stage of development, architects and manufacturers, seeing the desirability of getting away from the monotony of plain colors, started experimenting in glazes and colors, and a very

healthy demand was created for a wider range of colors and finishes, thereby giving new life and beauty to the modern American building in the transition from old to new methods. A period lapsed during which terra cotta, was trying to adapt itself to new conditions. Its use was greatly increased and architects, leaders in the profession, recognized the material as the one best adaptable for use in modern building construction, yet it was natural that there should, considering that the industry was itself in a state of transition, be shortcomings. It cannot be denied that there have been failures in terra cotta. We have all heard of them. Of the one hundred and one good jobs that were delivered in first class order and still stand up and are still attractive, we do not hear of; but the one bad job which failed is today an eye-sore and everybody is talking about it.

The problems which troubled us years ago are still troubling us. Conditions are constantly changing, and so today, as it was yesterday, the question is, if we must eliminate defects and failures, to adapt our material to the changed conditions. It is among others a question of proper construction; it is also an engineering question; a question of how to build so as to protect our product from the ravages of moisture and changing climate. It is also an important question for the ceramist to solve, a question of how to perfect the quality of the material, so that it will resist these climatic changes.

It would seem plausible to say that a material like ours which is burned from 1800° to 2200°F and covered with an absolutely impervious coat of glaze or semi-glaze slip, can stand up for thousands of years without changing, and so it can, if it were not for the fact that moisture through the joints or from the wall surrounding our material gets into the bond of our material and seeking the natural way of getting out again breaks through the surface, thereby causing what we call spalling and chipping, etc.

Another class of failure in terra cotta which we all well know is the breaking and chipping caused by contraction and expansion due to sudden changes in climate. We are up against a problem of adapting our material to the many varieties of severe climatic changes as we find them in the United States, where the climates range from the cold of the polar region to the heat of the tropics.

It is up to us terra cotta manufacturers to find a way of overcoming these difficulties, to solve the engineering problems, to make a material which will permit certain contractions and expansions. We must prevent moisture getting into the inside of our material and we must make our body and our glazes and slips so that they will act together. We must deliver a material which will not show cracks or crazed surfaces before or after being delivered to the building. It is with the idea of finding the proper body and the proper surface and slip, both of which will act together, that the work is now going on at the Bureau of Standards.

We are all, each for himself, constantly engaged in this work trying through our Ceramic Departments to solve these problems. But it was recognized that the question was not a question which could be entirely solved by the individual members; that considering the before-mentioned wide range of climatic conditions in the United States and considering that the manufacturers of terra cotta in the United States are scattered from east to west and are employing different methods in trying to arrive at a more perfect result, it was thought that by the investigation going on at the Bureau of Standards, the manufacturers would be able to arrive at a conclusion which could not otherwise be arrived at, or solved individually.

The work which has been going on at the Bureau of Standards consists of testing the burned material delivered by the different companies right along, and extended tests have been carried on as to the strength of the different materials, the breakage point, the porosity of the body, its coefficiency as regards the glazes. One of the tests being carried on at present consists of alternately submerging and freezing and then heating the pieces.

It is not up to the Bureau of Standards to tell us where we are right or where we are wrong. The Bureau will not be able to more than point the way, and it is up to the individual manufacturer to make his own deductions from the investigation made by the Bureau of Standards and form his own conclusions, and use the advice given him so that he may perfect his material.

There will, perhaps, never be any final result or conclusion as to the question whether a hard body is better than a soft, or a material burned to a very high degree of heat is more endurable than a somewhat lower burned material. It may be a question of the quality of the clay used, and the elasticity of the slips, either of which may be just as endurable as the other.

I have confidence, however, that the work done by the Bureau of Standards is of great value to the terra cotta industry, and that it will in the near future assist us in solving some of our problems. It is up to our ceramist from the wide knowledge gained through the investigation to make his own deductions and make same applicable in a practical way so as to fit the particular situation within his company.

NEW JERSEY TERRA COTTA CO.
NEW YORK CITY

REFRACTORIES QUESTION BOX

By E. E. Ayars

Questions

1. Does the grinding (coarse or fine) have anything to do with the resistance of a fire-clay brick to spalling?

2. What difference is there between the properties of a soft mud machine made and a hand made brick?

3. What is the best method of sampling fine ground fire clay for testing? Discuss straight clay and cement mixtures.

4. Can a customer form any judgment of the quality of a shipment by a test made on one brick? If not, how many samples should be used?

5. Can an iron free clay brick be made for blast furnace service?

6. Will results in service justify the expenditure and added cost necessary in order to make fire-brick mixes from definite percentages of definitely sized clay grains?

7. What effect do soluble salts (such as show on red burning clays as scum) have on the refractoriness of fire brick? Are the silicates formed with such salts in burning of low refractoriness?

8. What effect do sand and air inclusions (commonly called sand cracks or molding cracks) incident to hand molding, have on the service of hand made fire brick?

9. What is the cause of rapid failure of fire brick in the checker work baffles of oil-fired boilers, subjected to a temperature of 2300°F but against which the oil flame does not impinge? The failure consists of premature vitrification and carbonizing with subsequent fusion. Is this a result of subjecting the brick to a reducing atmosphere?

10. What is the reason for the more rapid failure, at a lower temperature, of fire brick subjected to reducing atmosphere, than will obtain with the same brick under oxidizing conditions?

11. What is the relative spalling tendency of fire brick under reducing and oxidizing conditions, respectively?

Question

Is laboratory control possible in the manufacture of refractories?

Discussion

"Laboratory control is being practiced in the manufacture of refractories. The extent to which such control is being used varies, from plant to plant, the particular grade of product being manufactured ofttimes being the determining factor.

"Fusion and burning tests made on various strata or veins of clay make it possible to determine whether or not certain sections in a particular vein should be used in any particular product. Accordingly, as far as the control of the finished product is concerned, it is possible to use the proper selection in mining and grading of the raw materials.

"In respect to laboratory control of the actual fabrication of the raw materials in the finished product, such tests as screening, dried strength, drying and burning shrinkage, give a check on how closely the specifications of manufacture are being carried out. This question rather implies

its own answer and while laboratory tests do not insure first class product without the organization and equipment for producing it there is no question but that the industry would not have progressed as far as it has without the use of laboratory tests."—L. C. HEWITT, LaClede-Christy Clay Products Co., St. Louis, Mo.

Laboratory control of metallic alloys, and of iron and steel production, has long been so standardized and simplified that we saw great possibilities about three years ago in adapting that general procedure to the manufacture of our own "refractory alloys." In producing moderately large quantities of specially blended products there must be some controlling factor or there is danger of great variations in physical and chemical properties of the finished product. It is especially vital when there are perhaps fifteen active mixes being manufactured practically at all times, each one of these mixes differing in certain essential properties from any other mix. In order to retain satisfactorily the confidence of our customers in such products these respective physical and chemical properties must not vary beyond certain tolerances from one year's end to another. A purchaser must know that the properties which proved satisfactory a year ago will be retained within very close tolerances when he orders the same mix six months or a year afterwards.

As is known to many of us, an ultimate, or even proximate analysis of a refractory specimen is a time consuming, tiring job. Aside from the time involved and the cost of a skilled, reliable ceramic chemist the writer felt that adequate laboratory equipment and current supplies would be out of proportion to our own volume of production. There would be danger of its becoming a burden and serious delay especially since there is no point in having laboratory tests completed on production specimens after production has been practically finished. The time to draw specimens is when the blending of the mix is completed and then to devise quick, reliable and simple tests so that the laboratory report is available before that particular blend goes further into production.

It is a rather difficult task to devise, and then to set chemical tolerances without analyzing specimens thus drawn from production, but by requiring a few significant reactions on the specimen in a temperature range where its sensitiveness to chemical attack is at an approximate maximum, chemical control of production is greatly simplified and speeded up.

There is no such thing as absolute precision in the chemical or physical characteristics of any product made by Nature or man. Brief experience along the lines above suggested will set tolerances that are close enough and do not interfere with moderately large quantity production.

Laboratory control of the physical properties is so well known that it would be a waste of space to discuss it in detail. Frequently considerable

ingenuity is required in special cases, besides the routine tests for viscosity, ultimate fusion, gassing, etc., under perhaps both oxidizing and reducing conditions. As an example, it is necessary for us occasionally to determine the safe tension "fibre stresses" to which a certain finished product will be exposed. The penetrability of certain other products must be held in close control, where these products are to be exposed to various groups of fused, non-ferrous alloys, or slags, under various pressures.

Where many different components are required, such as in our own problem, laboratory control should start with the receipt of each raw component. These should be bought and accepted only on certain tolerances. Much time, labor, and grief will be saved by doing so. There are many producers who are after maximum possible tonnage of one line of product, with perhaps a "by-product" line made from inferior clays. To those manufacturers laboratory control will probably not appeal.

But to the producer of highly specialized "refractory alloys" it has proved itself not only practical after three years of operation, but in our opinion it is most essential.—T. C. EAYRS, Gen. Mgr. Massillon Stone & Fire Brick Co.

The following points on the question are taken from the discussion on the floor of the Atlantic City Meeting.

"I want to call to your attention a rather horrible example of the results of not following laboratory tests. I know of a brick manufacturer, who furnished brick for a power plant over a period of a good many years whose product seemed not to be as good as it was formerly. Upon consultation with him we found they made no chemical analysis themselves but occasionally had some made on their clay. The manager of this concern assured me the clay was of uniform quality because he showed me the analysis. I was much interested to note that sixteen years had elapsed between the tests he was discussing. It is no wonder that a good many things might happen in that time".—J. D. CARTER, Philadelphia Quartz Co., Philadelphia, Pa.

"It seems to me the whole discussion has been merely on technical control of the raw materials. That is the simplest thing the refractories man has to deal with. I do not think many manufacturers today are not keeping fairly good check on raw materials. But that is only the beginning.

"We spoil the brick in the process of manufacture. When we have a poor brick it is not due to fusion but something else, due to the manufacturing process. It occurred to me that was not what the questioner wanted to know—he did not want to know whether it was a good thing to analyze the clay; he apparently is interested in the process of manu-

facture.—A. F. GREAVES-WALKER, Stevens, Inc., Stevens Pottery, Georgia.

"In this question of control, there is one point that might enter into the control of the production. We have a simple method of taking twenty-four bricks from each kiln and testing those for weight, size and volume. We use a simple test to do that and then we correlate that with the results of our mining trip inspections, whereby we give each month the places to work and the amount of clay taken per day from each place. In that way we can control the water content by checking the screens. Fortunately any change in the size of the screen will very soon change the water content. In dry press ware your screen size is pretty close, your water content cannot vary much and get a good brick. So we have three places in the process that we control."—(A MEMBER.)

"It would seem that if laboratory control is to be exercised anywhere it could be exercised by the manufacturer. You can take a single clay, for instance flint clay, and establish certain standards and live up to these standards for that clay. You can take your plastic clay and build up to a certain standard there and by regular checking know how closely you come to those standards. It does not appear, however, that anyone can say just what the true control would be. Probably our mixtures are not what they should be. Perhaps we do not always hit it in the right spot in the brick—it may be that the clay is not uniform. It might be the water content, for example. Perhaps if anyone were to condemn laboratory control, it might be because of the fact that they used the wrong method. It seems to me that it is the misapplication of the test rather than the failure of the test itself."—RAYMOND M. HOWE.

The question of laboratory control in the manufacture of Refractories, as stated, may have many applications. The Editor chooses to believe that the thought in the mind of the man who put the query should have been stated as follows: Is it possible to secure uniform quality and uniform size in refractories by the application of laboratory tests?

Within recent months the matter of uniformity has assumed a new light and all manufacturers recognize the importance of producing refractories which vary in size and quality only the smallest conceivable amount. Such production will in most cases require the further development of processes and the installation of additional equipment. It will mean added cost of manufacture but the consumer has long since indicated a willingness to pay a premium for a brick that would lay up with uniformly thin joints and give uniform service. However, many consumers will undoubtedly consider the manufacturer of uniform brick offered at a premium in the same class with the renowned Jesse James, but it is

economically impossible to give something for nothing. Uniformity in a refractory will add to the cost, but at the same time the consumer will enjoy a lower unit cost and many will take advantage of this. More and more refractories are being purchased on service instead of price only, as formerly.

It would not appear possible to regulate the uniformity of fire brick produced by the present methods, by the simple application of laboratory control methods.

The matter of fusion point and chemical analysis may be regulated in the control of the raw materials, but it is the slight variation in the character of different carloads of raw materials, and the considerable variation in process treatment from day to day which accounts for the lack of uniformity in the product.

It is taken for granted that any manufacturer considering laboratory control methods has first thoroughly prospected his mines and has plotted the different seams of clay from core drill analysis.

His attitude then in selecting his clays at the mine should be that of the man buying material on specifications, and every possible precaution be used in the mining, grading and loading to see that materials are up to a certain standard.

Given an intelligent control of chemical analysis of the raw material and the exclusion of all foreign matter it should be possible to so regulate the processes that further laboratory control was almost unnecessary.

In the February number of the *Journal* appeared a description of material handling and storage methods designed to secure uniformity in an electrical porcelain body. The system of bin storage is designed to care for from 360 to 450 tons of material while an open storage system capable of handling 1000 tons or more is described. In view of the large tonnages represented in the daily capacities of refractories plants it is probable that the open storage system would be most effective and least expensive. In choosing such a method it is important that adequate measures be taken to protect the open storage from foreign material, and all through the process dirt and such refuse as grease, etc., must be kept out of the material.

In some cases it would undoubtedly prove advantageous to put all plastic clays through a rotary drier before placing in storage.

Assuming that the matter of uniformity in the raw material is taken care of in mining and by adequate storage and handling methods, the process of grinding, screening and mixing presents a problem. Tramp iron and some iron from the mills and pans may be removed by a magnetic pulley. The screen sizes may be checked occasionally by screen analysis and erratic separations avoided by regular replacement of worn screens.

Proper grain sizes of grog and plastic clays should be determined according to behavior in service. These should be strictly adhered to and will not affect the process in any way except to indicate the type of grinding and molding treatment, *i. e.*, soft mud, stiff mud, dry press, etc.

The matter of mixing or tempering is important. It may be determined by trial whether the body is improved by double or triple milling or pugging. If the tests indicate three pug mills or additional wet grinding equipment for the preparation of one charge of brick mixture, the method should be altered to take advantage of the indicated improvement.

Moisture content is of great importance. The poidometer is used with marked success in measuring the amount of water fed to the brick mixture. In many cases they have been adjusted so delicately as to compensate for the moisture already in the clay. One of the most pregnant causes of variations in uniformity of fire brick is the hand of the "experienced" pan man or pugger on the water hydrant. The operators' judgment is never equal to the situation. Although a man may be able to produce a good column from his position at the pug mill, the limits within which a good column obtains may permit a variation of several per cent of mixing water. The writer is not convinced that the poidometer is the final answer but it is many steps ahead of the manual method.[1]

Molding methods are sometimes at fault. A variation in density and workmanship is often seen in brick produced at different hours of the day by the same hand molder. When hand molding is necessary and the clay comes to the molder in a uniform condition from time to time, it is not possible to jar the mold by some mechanical method, the effect of which has been predetermined, in order to eliminate the indifferent treatment of a tired molder.

In the case of stiff mud brick the auger speed, depth of die, die lubrication, repressing pressures and method of hacking on drier cars should be studied. The correct condition will vary with each type of clay or mixture.

Dry press pressures are variable but there is a correct pressure for each type of brick. The addition of pressure gage equipment to the dry press is indicated. Moisture of dry press mixtures should not vary and methods should be devised, in the study of grinding and mixing, to secure uniform tempering.

The determination of the cross-breaking strength on green brick will indicate the uniformity and homogeneity of the mixture. Variations in water content, grog content, size of grain and molding density may be noted. This test should be conducted on a set plan with respect to drying conditions and time.

Correct drying will have little or no effect on uniformity. Rapid drying often produces unsound brick and these are not marketable. The

[1] See "Question Box," *Bull. Amer. Ceram. Soc.*, **3** [3], 90–93 (1924).

practice of leaving hand-molded and repressed brick on the floor long enough for them to get leather hard and immediately setting them in the kiln is open to criticism. In this case most of the water that should come out in drying comes off with the water smoke. With some clays the excessive moisture during the water-smoking period softens the brick enough to change its size and shape. Such effects should be guarded against. Kilns are not efficient or satisfactory driers but there are many plants now employing this method.

Setting methods may sometimes be changed to eliminate kiln marked or misshapen brick, and thus reduce kiln losses.

Proper firing conditions should be determined and a regular schedule followed. Kilns will require redesign and rebuilding in many cases and regular repairs must be made so that proper firing conditions may be maintained. Overfiring of the ends of Newcastle kilns and of the rim of round down draft kilns may be eliminated by a study of local conditions. Some remedies may be found in the following list; redesign of kiln bottom, or fire boxes, change of coal or fuel, changes in setting method, setting farther away from bag walls (from 2 to 6 inches) admission of excess air over the fire, etc.

In conclusion, the solution of the laboratory control problem is to first refine the manufacturing processes. Laboratory methods will aid materially in determining to what extent the refinement shall be carried, and simple tests may be devised to maintain control of the new methods.

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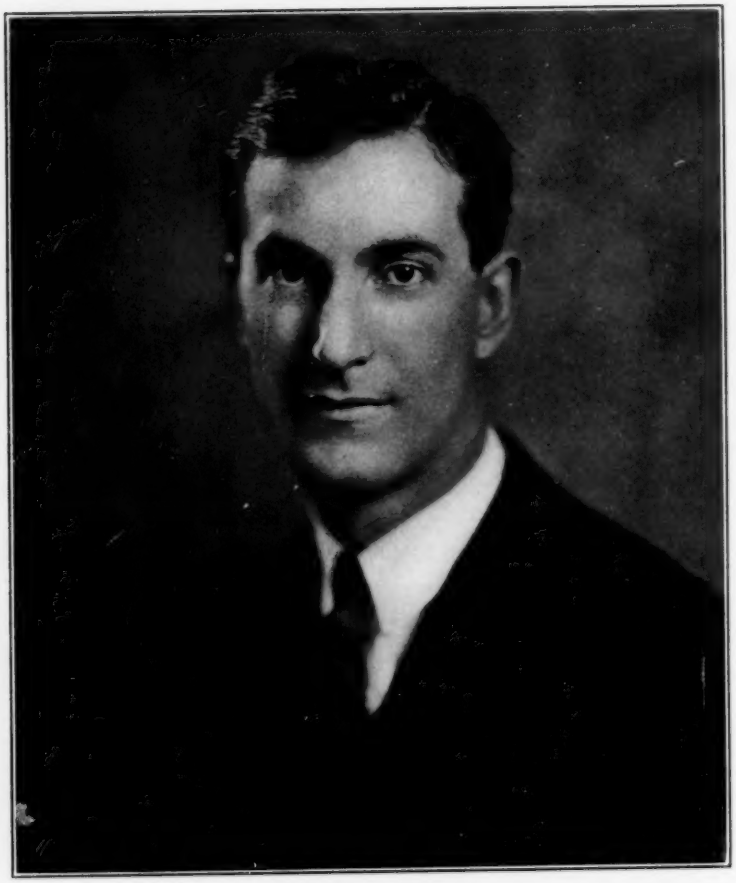

R. M. Howe

RAYMOND MILLER HOWE

The death of Raymond Howe on April 1 was a great loss not only to the many friends whose privilege it had been to know such a sterling man, but to the interests of ceramics in general. He was a specialist in refractories, but he had also broad knowledge of ceramics, and his warmly sympathetic interest in the profession and in the AMERICAN CERAMIC SOCIETY led to prominent activities on his part that will be missed generally. None, however, save the close friends who knew the rich treasures of his mind, as revealed in familiar conversation, can realize how great is the loss which ceramics has sustained in his death at the early age of thirty. For while Howe was a generous contributor to ceramic literature, there is a point of view from which it may be fairly urged that the work which rare and original minds fall short of doing because of brevity of life does never really get done at all. Something similar to it is performed, no doubt, but is done in a different order of causation; and though there may seem to be equivalence, the fact remains that, from the sum of human effort, an indefinite amount of rich and fruitful life is lost. True as this is in the case of science, it is still more obviously true in technology. Howe had an intellect that was outstanding from its happy union of acuteness with researchfulness. Very few ceramists were superior in balance of mind and in extent of literary acquirement. It is a bitter thing to lose a productive thinker of this mold, just in the prime vigor of life, and at a time when his ability was receiving recognition in industry as well as in the SOCIETY.

Raymond Miller Howe was born at Elmira, N. Y., March 15, 1894, the son of the late Mr. and Mrs. H. C. Howe. He received his preparatory education at Riverside School and the Elmira Free Academy. He was graduated at Alfred University in 1915 (B.S. in ceramics) and then came to the Department of Chemistry of the University of Pittsburgh to pursue graduate work under Prof. Alexander Silverman. He received his M.A. degree in 1916, served as instructor in chemistry for a year, and was appointed an industrial fellow of Mellon Institute in 1917. While at the Institute, 1917–23, he was senior incumbent of the Multiple Industrial Fellowship sustained by the Refractories Manufacturers Association, a position that he occupied with distinction and in which he acquired an international reputation because of his published contributions to the literature of refractories. Early in his career at Mellon Institute Howe became active in the affairs of the Robert Kennedy Duncan Club, the organization of Fellows, and in the American Chemical Society (secretary, Pittsburgh Section, 1917), and the AMERICAN CERAMIC SOCIETY (secretary, Refractories Division, 1919; trustee, 1920–1924; vice-president, 1924). He served on the advisory committee of the War Industries Board during the World War and was an interested member of the American

Society for Testing Materials and of its committee on standardization of refractories. On April 1, 1923, Howe entered the employ of the Kier Fire Brick Company, of Pittsburgh, Pa., as assistant to the president, and shortly before his fatal illness it was decided by the directorate of the company to make him a vice-president in recognition of his technical and executive value.

Howe's first research was on the silvering of mirrors. His subsequent investigations related to fire brick, refractories, and underglaze colors. A list of some thirty of his published papers is appended to this necrology. At the time of his death he had in course of preparation a comprehensive treatise on "The American Refractories Industry," collaborating with J. Spotts McDowell, of the Harbison-Walker Refractories Company, of Pittsburgh, Pa.

He is survived by his widow, Mrs. Ethel Williams Howe, and by three children, two sons, Charles and Raymond Howe, and a daughter, Catherine Howe.

The funeral took place at the home of his uncle, Charles Howe, 456 Maple Avenue, Elmira, N. Y., on April 4. The services were conducted by the Rev. Albert G. Cornwell, of the Park Church, of which the deceased was a member. Rev. Cornwell was assisted by Prof. C. F. Binns, of Alfred University. The pall bearers were Samuel M. Kier and Porter S. Kier, of the Kier Fire Brick Company; M. Grover Babcock, of the Pittsburgh Plate Glass Company; and E. Ward Tillotson, Henry A. Kohman, and Stuart M. Phelps, of Mellon Institute. Burial was in Woodlawn Cemetery, Elmira, N. Y.

E. WARD TILLOTSON

A List of the Journal Contributions of Raymond M. Howe

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ACTIVITIES OF THE SOCIETY

THE PRESIDENT'S PAGE

By Robert D. Landrum

The Ceramic Institute—a new idea and one very much worth while. The "virus of coöperative research is still taking."

Twenty-seven years ago a small group of men innoculated the clay-working industry with this "virus" and the result was the organization of our Society. The results of this innoculation were local at first combining for group activity those few whose education fitted them to make use of the results already obtained by scientific workers in the field of the physics and chemistry of the silicates.

Little real research in this field had been accomplished up to this time and each individual worker had a large obligation to perform. The Ceramic Schools were fostered and gradually the number of men with special training and the scientific point of view was increased. The various government bureaus were influenced to recognize the need of research in the ceramic industries and through coöperation with our society provided laboratories and there our members have gone far in their accomplishments in our field.

A long step toward increasing our usefulness was made when the scope of our activities was enlarged to include all the silicate industries. In fact this step has changed the previously accepted definition of the word "ceramic." Next came the movement which gave us our full time executive secretary and his very efficient associates.

And now comes this new idea—The Ceramic Institute. The idea has sprung from several different sources and under as many different names, but in each case it has originated in a trade association. Each time from a group of men associated for commercial purposes. This means much.

Here is our opportunity to again increase our field of usefulness. You members of the American Ceramic Society who are in these associations know that by acting with us they can save duplication. Advise them of this fact. They can employ a "going" organization. An organization with a world-wide prestige of wonderful things accomplished. For twenty-seven years American ceramists have collaborated in the American Ceramic Society through our conventions and publications and established a record of which all may well be proud.

The American Ceramic Society members are loyally determined that their organization shall be and do things productive of the greatest benefit to all who will labor with them. There has been no hesitancy in changing procedure or direction of activities when such was thought to be beneficial and there would be no hesitancy now to so alter our affairs that the Ceramic Institute could be brought into active being.

Our Society is incorporated under the laws of the State of Ohio; it has a Constitution and a form of organization to which there is rigid adherence. These bespeak solidarity and orderliness in purpose. We do not represent the prejudices or special purposes of any person or group of persons.

Our Society is unique in that it is devoted *exclusively* to the promotion of the technical, scientific and artistic advancement of the Ceramic Industries. Questions of trade, tariff and traffic are not within its scope. We are here to promote scientific research, to assist and guide all desiring our assistance or leadership.

Our Society is unique also in that it represents the interests of all ceramic groups and agencies, each and every Silicate Industry, the colleges, the federal bureas, the suppliers of materials and equipment and the Trade Press. Of course, while rights of each group are equal, the benefits are in proportion to their representation and activity. The essential thought I want to bring out is that if the several trade associations will get together in the support of a Ceramic Institute for the purpose of centralizing and planning coöperative research, they would do well to consider using our editorial and

committee organization. Our SOCIETY, a successful, going organization is theirs if they will but use it.

We are growing in strength and in service but feel that as yet we have hardly started. This is a plea, against duplication of effort and expenditure by the trade associations, and for a broader field of service for us.

The SOCIETY was intended to be, and is anxious to be in the largest way a collaboration of all ceramic groups. It requires nothing but the determination of the ceramic trade associations to make the SOCIETY include all that they have in mind that the Ceramic Institute shall be.

I am writing this in Boston where I have spent the day with Dr. Stratton, President of the Mass. Inst. of Technology. Next month perhaps I can tell you how this great University of Science and Technology is planning to coöperate for greater service to the Ceramic Industries.

MEMBERSHIP WORKERS' RECORD

This is the "flux" season in memberships; some have engaged in fields other than ceramics; some have not felt the urge to send in their subscription fee and yet others have changed their status from personal to corporation representative. We mourn the loss of five by death.

May 1 is the time of physical inventory of members and the dropping of the "no response" group; "pruning to the quick," leaving only the vigorous growth. This job is detested but the results in time are pleasing.

This letter from M. E. Manson of Rundle Mfg. Co., is typical of several received recently. They tell in very plain words of a growing industrial appreciation of collaboration in research and education.

"The time has now come when my Company feels that it should have a corporation membership in the AMERICAN CERAMIC SOCIETY. At the same time I wish to keep my personal membership."

Here are the March workers and the fruits of their labor:

	Personal	Corporation		Personal	Corporation
G. Percy Cole	1		C. H. Lawson	1	
M. R. Cuthbertson	1		M. E. Manson		1
Robert F. Ferguson		1	Frank G. Roberts	1	
M. L. Hartman	1		John Sawyer	1	
F. A. Harvey	1		Mary G. Sheerer	1	
S. C. Hemsteger		1	Eric B. Turner	1	
H. A. Huisken	1		Robt. Twells, Jr.	1	
Everett C. Hunting	1		Hewitt Wilson	2	
F. G. Jaeger	1		Office	16	
W. F. Landers, Jr.	1			—	—
R. D. Landrum	3		Total	35	3

	Personal	Corporation	Totals
Net Roster, March 14	1992	299	2291
Acquisitions to April 15	35	3	
	2027	302	
Withdrawals	2	2	
Deaths	5		
Net Roster, April 14	2020	300	2320

NEW MEMBERS RECEIVED FROM MARCH 15 TO APRIL 15

PERSONAL

Allan, John Caldwell, 263 St. James St., Montreal, Canada. Mining Engineer.

Alleman, Fred Franklin, 2940 Harding Ave., Detroit, Mich. Dressler Kiln Operator, Champion Porcelain Co.

Baddeley, Frank, 206 E. California St., Walnut Park, Glendale, Cal. Instructor in Ceramics, Lincoln High School.

Barber, Lyman F., Sales Engineer, Southwestern Engineering Corp., 12th Floor, Hollingsworth Bldg., Los Angeles, Cal.

Bedson, Will, Lawrence Road, R. F. D. 4, Trenton, N. J. General Manager, Elite Pottery Co.

Breneman, John C., Builder and Installer of Furnaces, Bowley Lane and Philadelphia Rd., Baltimore, Md.

Broomall, Grant C., Director of Service Engineering, The American Rolling Mill Co., Middletown, Ohio

Clark, Roland J., Student, N. Y. State School of Ceramics, Box 92, Alfred, N. Y.

Curtis, Edmund de Forest, Wayne, Pa., Proprietor Conestoga Pottery, Instructor Pottery, Penna. Museum and School of Industrial Art, Philadelphia, Pa.

Darby, Geo. M., Research Engineer, The Dorr Co., Westport, Conn.

Dorst, Max, Maschinenfabrik vorm Georg Dorst A.-G. Sonnenberg-Oberlind (Thür), Germany.

Easter, George J., 634 Elmwood Ave., Niagara Falls, N. Y., Assistant Director of Research, The Carborundum Co.

Eigenbrot, Edwin A., 3500 N. 2nd St., St. Louis, Mo. Supt. Enamel Dept., The Bucks Stove and Range Co.

Farnsworth, Richard M., Harvard St., Lancaster, Mass. Miner of Fuller's earth.

Fosseen, A. B., President and General Manager, Washington Brick, Lime and S. P. Co., Spokane, Wash.

Grady, R. F., Jr., 24 W. Frambes Ave., Columbus, Ohio. Student, Ohio State University.

Harcourt, Harry E., 805 Bank of Hamilton, Toronto, Canada. Manager, Industrial Minerals Corp. of Canada, Ltd.

Huot, Constant John, 7353 Denniston Ave., Swissvale, Pa. Glass Chemist, Pittsburgh Lamp Brass & Glass Co.

Kennedy, F. J., 150 Nassau Street, New York City, Gen. Mgr., West Gas Improvement Co. of America, Inc.

Lacy, Roy, 634 S. St. Andrews Pl., Los Angeles, Cal. Assistant General Manager, Pacific Clay Products, Inc.

Leming, Frank, LaOroya, Peru, South America. Cerro de Pasco Copper Corp.

Lowrance, R. E., Beaver Falls Art Tile Co., Beaver Falls, Pa.

Martin, Geoffrey, Rosherville Court, Burch Rd., Graves Eng, Kent, England. Director of Research of Brit. Portland Cement Research Association.

McGrath, Leigh John, Civil Engineer, 1540 S. Walnut St., Casper, Wyoming.

Moran, J. J., 610 Ward St., Vineland, N. J. Assistant Chemist, Kimble Glass Co.

Perham, Alfred C., West Paris, Me., Owner of Quarries.

Pollard, J. A., 503 Union and Planters Bank Bldg., Memphis, Tenn.

Reese, Lemuel V., 813 Cross Ave., Elizabeth, N. J. Chief Engineer, U. S. Metals Refining Co., Carteret, N. J.

Schneider, N. L., District Representative, United Alloy Steel Corp., 614 Swetland Bldg., Cleveland, Ohio.

Sloteman, Ambrose M., 27 S. Fairview St., Lock Haven, Pa. Salesman, Crescent Refractories Co.

Smith, Wm. H., General Manager, Franklin Porcelain Co., Box 83, Norristown, Pa.

Straumford, Joe Franklin, 762 Savier St., Portland, Ore. Asst. Supt., Portland Plant, Denny-Renton Clay & Coal Co.

Sutterlin, Frederick, Supt. Maddock Pottery, Trenton, N. J.

Tobitt, F. A., Sales Dept., The American Rolling Mill Co., Middletown, Ohio.

Van Gelderen, F. M., Enschede, Holsland.

CORPORATION

Garfield Fire Clay Co., Robinson, Ind. Co., Pa. Manufacturers of Refractories, F. E. Robinson, Treas.

Mt. Clemens Pottery Co., Mt. Clemens, Mich. Semi Porcelain Dinnerware, Chas. E. Doll, Treas. & General Manager.

Rundle Mfg. Co., Milwaukee, Wis., Enameled Sanitary Ware, Albert C. Held, Sec.

PERSONAL NOTES OF MEMBERS

Donald B. Atwell has notified the Secretary's office that his present address is 4921 Page Boulevard, St. Louis, Mo.

C. P. Blatchley, until lately of Manor Park House, Worksop-Notts, England, is now living at Parkfield. Mr. Blatchley is manager of the Steetley Lime Co., Ltd.

Oscar Brewer, who has been connected with the Leeds and Northrup Co., of Philadelphia as Sales Engineer, has been placed in charge of the office recently opened by that Company in Cleveland, 1217 Union Trust Bldg.

Emil Bronlund has moved from Alberta, Canada, to Seattle, Wash., 3909 E. Howell Street.

Herman Coors is now living at 5469 Ninth Ave., Los Angeles, Calif.

Arthur De Vol gives as his address 964 Brighton Blvd., Zanesville, Ohio.

Richard D. Ferguson has moved from Lincoln, Nebr., to 1018 Wells St., Apt. 49, Milwaukee, Wis.

Robert F. Ferguson, Secretary of the Refractories Division is located in Bolivar, Pa., Box 74.

R. B. Gilmore of Cleveland recently became affiliated with the Carborundum Co., and is living at 521 Jefferson Ave., Niagara Falls, N. Y.

R. P. Herrold of the Mosaic Tile Co., Zanesville, Ohio, has been appointed representative for the Company's corporation membership in this Society.

Z. C. Kline of the General Electric Co., has been transferred from the Rhode Island Glass Division of that Company at Central Falls, R. I., to the Niles Glass Division, Niles, Ohio.

T. A. Klinefelter is now associated with the Hercules Porcelain Co., Box 124, Belvidere, Illinois.

S. Y. Liu, formerly of Boston, Mass., is now employed as engineer for the Chen Kwong Ceramics Co., Hong Kong, China. His address is % Lai Sang Choung, 297 Queen's Road.

H. S. Magid is located at 103 Perry street, Tiffin, Ohio. He is employed with the Standard Porcelain Mfg. Co., Tiffin Works.

Frank B. Mahoney is employed as superintendent of the Enamelware Division, the Humphryes Manufacturing Co., Mansfield, Ohio. Mr. Mahoney's home was formerly in Chattanooga, Tenn.

Crawford Massey is with the West Coast Plant of the American Encaustic Tiling Co., and his address is 492 E. 46th St., Los Angeles, Calif.

Louis Navias, in the past year a special expert in the Ceramic Division of the U. S. Tariff Commission has joined the Research Staff of the General Electric Co., Schenectady, N. Y., as ceramic chemist.

Carl Perg has moved from Des Plaines, Ill., to 609 W. Kalamazoo Ave., Kalamazoo, Mich.

Robert D. Pike has written that his new address is 582 Market St., San Francisco, Calif.

W. H. Powell has requested that his mailing address be changed from 350 Madison Ave., N. Y., to 41 Plymouth St., Montclair, N. J.

E. E. Pressler has concluded his work with the Bureau of Mines, Ceramic Experiment Station, Columbus, Ohio, and has left for his home in Tosca, Texas.

P. B. Richardson, representative of the Harbison-Walker Refractories Co., has notified the Secretary's office that his correct mailing address is 200 Devonshire St., Boston, Mass.

Wallace C. Riddell, of Berkeley, Calif., has changed his address from 2544 Buena Vista Way to 1960 El Dorado Ave.,

Robert Roadhouse, formerly of Norwalk, Ohio, has moved to Clyde, Ohio.

Drew M. Thorpe, formerly of Pittsburgh, Pa., is at present employed in the Buffalo, N. Y., office of the General Refractories Co.

L. A. Vincent will soon leave Tottenville, S. I., N. Y., and can be addressed at Box 243, New Castle, Pa.

S. Paul Ward has recently moved from McGill, Nevada, to 1200 Oak Grove Ave., Los Angeles, Calif.

Eugenie A. Worman, who has been teaching pottery at the University of Washington, has moved to 4809 Beach Drive, Seattle.

RESOLUTIONS ON THE DEATH OF MR. BUCK

February 14, 1924.

At a meeting held in Atlantic City on February 5, the Enamel Division of the AMERICAN CERAMIC SOCIETY took the following action: The Chairman of the meeting, Mr. H. F. Staley, called attention to the sudden death of one of our fellow members, and motion was made of the contribution of a scientific nature made by Mr. Daniel M. Buck.

A committee was named to draw up a resolution. This committee consisted of

Mr. R. D. Wells, Floyd-Wells Company, Royersford, Pennsylvania,

Mr. Emerson P. Poste, Elyria Enameled Products Company, Elyria, Ohio,

Mr. J. A. Aupperle, The American Rolling Mill Company, Middletown, Ohio.

RESOLVED: That the Enamel Division of the AMERICAN CERAMIC SOCIETY desires to record its feeling of deep regret at the untimely death of one of its members and coworkers, Daniel M. Buck, Metallurgist for the American Sheet and Tin Plate Company.

RESOLVED: That the AMERICAN CERAMIC SOCIETY express its appreciation of the scientific contributions made by Mr. Buck and their influence on the study of special problems which engaged his efforts. Therefore be it further

RESOLVED: That this expression of the appreciation of his wisdom and impartial coöperation in the work on enamel problems be published in the bulletin of the AMERICAN CERAMIC SOCIETY; and be it also further

RESOLVED: That a copy of this resolution be sent to Mrs. Daniel M. Buck, 6945 Meade Street, Pittsburgh, Pennsylvania, and to Mr. Eugene W. Pargny, President of the American Sheet and Tin Plate Company, Frick Building, Pittsburgh, Pennsylvania.

NECROLOGY

John Betteley and John Cuffin

Word has been received of the deaths of John Betteley of Ferndale, Mich., on March 28, 1924, and also of John Cuffin of Portland, Ore. Mr. Cuffin died very suddenly July 13, 1923, but word of his death has only now reached the office of the Secretary.

LOCAL SECTION NOTES

Pittsburgh Section.—The officers of the Pittsburgh Section of the American Chemical Society held a joint meeting with the Pittsburgh AMERICAN CERAMIC SOCIETY on April 17 at the Pittsburgh Station, U. S. Bureau of Mines. The motion picture "The Story of Refractories" was presented. "The Manufacture of Refractories" was presented by J. Spotts McDowell. McDonald C. Booze talked on "The Testing of Refractories." An open discussion was held on "The Application of Refractories."

St. Louis Section.—The St. Louis Local Section of the Society held a meeting on April 22. Particulars of this meeting will be given in the next issue of the *Bulletin*.

REPORT ON PATCHING CEMENTS

BY C. W. HILL[1]

Following the St. Louis meeting, a committee was appointed to investigate Patching Cements. Information was received from nearly all the Terra Cotta Companies regarding the cements in use. The field was divided among the members of the committee and a uniform method of testing agreed upon. This also provided for a certain amount of duplication among the workers to give a check on the results of the individual. Test pieces were made.

The actual experimentation was not promptly carried out, the reason being given that the workers were too busy to do the work. Two of the committee later changed their connections, and were unable to do any work.

Some work was done by W. L. Howat and assistants on the commercial cements. The preliminary results indicated that cements of the basic phosphate type are better suited than some of the commercial cements on the market. Further investigation would include a study of the best compositions of this type of cement and correlation of these results with those on the dental cements with which it is allied. It has been impossible for over a year to revive this work.

The committee has but little to add to the common knowledge of this subject. It was clearly indicated by the original replies that at that time none of the companies had investigated the subject thoroughly. The tests reported thus far indicate a wide variation in the value of various cements in use, some of those being of poor quality.

On account of the incompleteness of the results, and the consequent danger of incorrect conclusions, this report is made without experimental data.

[1] Chairman of Committee.

It is clearly a field which should be investigated. Our experience would indicate the extreme difficulty if not impossibility of investigating the subject properly and in a reasonable time by means of individual ceramists working in coöperation. Apparently few of the companies have a large enough staff of ceramists to be able to assign a man to work on the problem intensively.

While the problem could be cleared up by one man in a fairly short time, it is one in which all companies are interested. The suggestion has, therefore, been made to the National Terra Cotta Society that they consider referring the problem to the Bureau of Standards to be handled at the same time with other investigations now under way.

MANY INVITATIONS RECEIVED

Western Manufacturers Eager to Entertain

The following firms of the western coast have extended to those members of the SOCIETY who will attend the Pacific Coast Meeting the cordiality of their welcome. Members of the East and Mid-west are assured of the finest trip both in scenic value and of interest to technical ceramists that the SOCIETY has ever sponsored. The dates are July 21 to August 20.

Henry Weiss, West Coast Porcelain Mfrs., Millbrae, Calif.
H. C. Elliott, Pres. Cascade China Company, Portland, Oregon.
H. R. Kreitzer, Secy., Columbia Brick Works, Portland, Oregon.
J. B. Watson, Mgr., Idaho Fire Brick Company, Troy, Idaho.
Carl F. Kneisel, Secy., Sheridan Press Brick & Tile Co., Sheridan, Wyoming.
R. M. Bard, Asst. Mgr., American Fire Brick Co., Spokane, Wash.
Paul S. MacMichael, Pres. Northern Clay Company, Auburn, Wash.
L. R. Burdick, James Graham Mfg. Company, Newark, California.
A. J. Gladding, Gladding, McBean & Company, San Francisco, Cal.
John T. Roberts, Mgr., Stockton Fire Brick Co., San Francisco, Cal.
F. A. Costello, Pres., California Pottery Co., San Francisco, Cal.
N. W. Stern, Pacific Sanitary Mfg. Co., San Francisco, Cal.
R. B. Keeler, California Clay Products Co., South Gate, Cal.
Findlay M. Drummond, Alberhill Coal & Clay Co., Los Angeles, Cal.
H. B. Potter, Secy., Los Angeles Pressed Brick Co., Los Angeles, Calif.
H. S. Thatcher, Gen. Mgr., Celite Products Co., Los Angeles, Calif.
R. B. Ahlswede, Secy., California Metal Enameling Co., Los Angeles, Calif.
F. B. Ortman, Vice-Pres., Tropico Potteries, Inc., Glendale, Calif.
Earnest H. Batchelder, Batchelder-Wilson Co., Los Angeles, Calif.
Fred H. Robertson, Claycraft Potteries, Los Angeles, Calif.
C. D. Gram, Vice-President, Vitrefrax Company, Los Angeles, Calif.
W. G. Brady, Secy., Pacific Clay Products, Inc., Los Angeles, Cal.

George P. Fackt, Northwestern Terra Cotta Co., Denver Division, has extended in the name of the Colorado members a welcome to Denver and Colorado Springs, to their ceramic plants and their social facilities.

A great trip from Chicago to Spokane, Seattle, Portland, San Francisco, Lincoln Los Angeles, Denver, Colorado Springs, and return. A personally conducted tour, hotels and all conveniences arranged, a splendid mixture of sight seeing, social intercourse, plant visit and technical meetings that will not for a long while be surpassed. Our Western members guarantee these and the facilities are provided.

NOTES AND NEWS

BUREAU OF STANDARDS

Opportunity for Ceramists

The National Bureau of Standards, which is continually being called upon more and more to investigate problems in the interests of American industrial development, is at this time offering unusual inducements to young men who wish to avail themselves of the opportunity of training in investigational work. This is particularly true of the Ceramic Division. This Division has for many years supplied the industry, in a large measure, with technically trained men, and the demand made upon it has been so great as to exceed the supply. There are at this time several openings, offering exceptional opportunities for men interested in all ceramic lines, more especially whiteware, both for graduates and for men who have had one or more year's experience in the field. Applications should be filed through the Director, Bureau of Standards, Washington, D. C.

Increasing the Strength of Lime Blocks

Previous work by the Bureau indicated that when cast lime blocks have the same distribution of core space as gypsum blocks they will have about the same weight but less strength. It has been found that by changing the design of a block so that the total volume of core space is the same but is contained in two elliptic cores instead of four circular cores the strength of the block can be increased sufficiently to meet the requirements now put upon gypsum blocks. This work has been conducted in coöperation with the National Lime Association and a final report on the matter has been transmitted to that organization.

Recommended Specifications for Ceramic Whiting

Circular No. 152 of the Bureau of Standards, obtainable from the Superintendent of Documents, at 5 cents a copy consists of the fifth of a series of specifications for the kinds of lime required by different chemical industries. The preceding four dealt, respectively, with lime used in cooking rags, in causticizing, and in the manufacture of sulphite pulp and glass. This deals with lime used in making glazes, enamels, and similar ceramic products. Ceramic whiting is really calcium carbonate, with or without a small amount of magnesium carbonate, but it performs the function of lime. It should contain not less than 97 per cent of carbonates, and should be very fine, so that 98 percent of it will pass a No. 200 screen.

Recommended Specifications for Quicklime and Hydrated Lime for the Manufacture of Sand-Lime Brick

Circular No. 150 of the Bureau of Standards, copies of which may be obtained from the Superintendent of Documents at 5 cents a piece, covers the sixth of a series of specifications for the lime used in various chemical industries. To assist in the development of these specifications, the Bureau has called together an Interdepartmental Conference on Chemical Lime, composed of representatives of the Geological Survey and Bureau of Mines of the Interior Department; the Bureau of Soils, Bureau of Chemistry, Forest Service, and Fixed Nitrogen Research Laboratory of the Department of Agriculture; and the Chemical Warfare Service of the War Department. The present specification, based on a draft originally prepared by W. E. E mley, of the lime section, Bureau of Standards, has been unanimously approved by the above conference and by the National Lime Association.

Either quicklime or hydrated lime may be purchased for making sand-lime brick, but the former must be completely hydrated before it can be used. Material of about 85 percent purity and reasonably low in magnesia is required. The lime must also be reasonably fresh, as indicated by a low content of carbon dioxide. Methods of analysis are given in detail.

Recommended Specification for Quicklime and Hydrated Lime for the Manufacture of Silica Brick

Bureau of Standards Circular No. 153 covers recommended specifications for quicklime and hydrated lime for the manufacture of silica brick. A brief description of the way in which lime is used for this purpose is followed by a general statement as to the quality of lime required.

The standard of quality is set at 92 percent based on the non-volatile matter, with maximum limits of 5 and 10 percent carbon dioxide, depending upon whether the sample is taken at point of shipment or of destination.

Complete directions for sampling and testing are included. Copies may be obtained at 5 cents a piece from the Superintendent of Documents.

Equalizer Apparatus for Transverse Tests of Bricks

In Technical News Bulletin No. 79, Item 20, brief mention was made of the apparatus designed by H. L. Whittemore for the transverse testing of bricks.

A description of this apparatus is now available in printed form as Technologic Paper No. 251 of the Bureau of Standards, copies of which may be obtained from the Superintendent of Documents at 10 cents a piece.

The new equalizer apparatus consists of two equal arm levers about the length of the brick, mounted side by side on a pin at the middle of their length. At each end the levers have barrel-shaped knife edges carried on vertical spring-steel plates, which allow longitudinal movement of the knife edges. The levers equalize the four forces acting upward on the lower surface of the brick. The upper knife edge and the bearing plate are self adjusting.

Refractories for Boiler Settings

At a recent conference of the committee on refractories of the Federal Specifications Board the tentative specifications for boiler setting refractories were revised to meet the suggestions submitted by the industry and by the various Government departments since their promulgation as "tentative." The specifications as revised will be submitted to the Federal Specifications Board. At the conference it was further decided to take up the preparation of specifications for fire clay used as a mortar and for the so-called "plastic" refractories used in building rammed-up boiler linings.

Experiments with Glass House Refractories

As mentioned in Item 4 of Bulletin No. 83 the Bureau has been carrying out some experiments on the composition and method of making the "cut offs" used in controlling the flow of glass to automatic bottle machines. During the month one complete set of these "cut offs" consisting of 25 shapes has been cast. For this work a mixture of clay and grog that has been found to be resistant to glass attack and spalling was used. Four additional shapes of a second set, the body composition of which is somewhat different as to grog sizing as well as grog-feldspar content, have also been cast. The ten shapes reported as cast during the last month have been burned. A plaster mold has been completed for casting "flow spouts" which are used in connection with the cut offs," the proper specific gravity for the slip in this process has been determined, and six of these shapes have been cast. The same bodies used in the manufacture of the "cut offs" are being used in making up the "flow spouts."

The Abrasive Hardness of Ceramic Glazes

The glazes on six brands of vitreous ware and two glazes prepared at the Bureau were tested for abrasive hardness during the past month. The two Bureau glazes, although of typical composition, showed much greater abrasive hardness than any of the glazes on commercial ware and somewhat greater hardness than porcelain glazes. The hard glazes were found to be comparatively thin and yet they were as satisfactory in appearance as the thicker ones. It therefore appears that thick-

ness may have an important bearing on the hardness of ordinary commercial glazes and this phase of the problem will be given further study.

The Thermal Dilation of Ceramic Materials

Scientific Paper No. 485, which may be obtained from the Superintendent of Documents at 5 cents a copy, describes an interference method and apparatus for measuring the thermal expansion of ceramic materials. The samples, in the form of small pins, 0.5 to 10.0 mm. in length, are placed between two fused quartz interferometer plates and heated in an electric furnace. The elongation of the samples is determined from the number of interference fringes that pass reference marks on the interferometer plate while the sample is being heated. A change in length of the sample of one-millionth of an inch can be easily detected. In order to show the application of this method to the study of the expansion of ceramic materials, measurements were made on several samples of glaze, terra cotta, tile, porcelain, and clay in the temperature interval 20° to 1000°C. Some of the samples were especially prepared, while others were taken from finished products, some of which had failed in service.

BUREAU OF MINES NOTES

Research Fellowships Offered

Starting with the school year, October 1, 1923, three fellowships were initiated at Ohio State University as a result of a coöperation between the U. S. Bureau of Mines and The Engineering Experiment Station of Ohio State University. The fellowships, which carry a stipend of $750, are for the purpose of securing data in the ceramic field. The investigations are carried on in the laboratories of the Bureau of Mines and are jointly directed by the staff of the Bureau and the head of the college department in whose field the particular research falls. During the past year the following problems were investigated:

1. The cause of volume changes in fire brick during heat treatment.
2. Dolomite investigation No. 3 (binders and method of fabrications).
3. Utilization of pebbly clays for heavy clay products manufacture.

These fellowships for the coming school year will be filled about May fifteenth. More detailed information can be obtained in regard to the character of the work or in regard to the qualifications required of an applicant, by addressing an inquiry to either: Dean E. A. Hitchcock, Director, Engineering Experiment Station, Ohio State University, or G. A. Bole, Superintendent, U. S. Bureau of Mines Experiment Station.

Higher Salaries for Ceramic Engineers

The United States Civil Service has recently advertised an examination open to ceramic engineers for government service, the salary ranging from $3800 to $5000. These salaries are considerably higher than any hitherto offered for a similar opening in government service, and hence should attract experienced engineers in the ceramic industry.

COLLOID SYMPOSIUM AT NORTHWESTERN UNIVERSITY

Ceramic Papers Scheduled

Members of the AMERICAN CERAMIC SOCIETY will be interested in the announcement of the program of the Colloid Symposium to be held at Northwestern University, June 19, 20, and 21. Among the speakers appearing on the program are the following, whose subjects will be of interest to ceramists.

A. V. Bleininger, "Properties of Clays."

Eugene Bingham, "Fluidity and Plasticity in Colloid Control."
Jerome Alexander, "Bentonite and Other Colloidal Clays."
W. J. Kelly, "The Determination of Size of Particles and Their Control."
F. P. Hall, "The Effect of Hydrogen-Ion Concentration on Clay Particles."
There are other important papers on the program, but the above are of especial concern to ceramists.

NATIONAL LIME ASSOCIATION MEETING

The National Lime Association will meet on May 20, 21, 22, 23 at the Greenbrier Hotel, White Sulphur Springs, West Virginia. The program will include not only a report of the activities of the Association, but there will also be scheduled certain special features, such as a Golf Tournament.

COMMON BRICK MANUFACTURERS ASSOCIATION CONSIDERS PROPOSAL OF A CERAMIC INSTITUTE[1]

The cement industry has a concrete Institute, which functions to disseminate authoritative data on concrete, and whose findings are given greater prestige than if issued by the Portland Cement Association and are listened to with greater respects by architects, engineers, Government departments, and the public.

A Clay Products Institute can be organized to speak in the same way for this industry, face brick, hollow tile, drain tile, flue linings and sewer pipe, refractories and pottery, at no greater cost at the start than that required for a desk, letter heads, and the salary of a director.

The Concrete Institute appears to be in close touch with Lewis Institute, a concrete testing laboratory run under the able direction of Prof. Abrams.

We do not propose to build a laboratory. Instead, the director would correlate the work of the research departments of the Universities, the Government Departments and other testing agencies supported already by the taxes every brick man pays.

The present Ceramic Society has offered to act as the nucleus of the proposed Institute, and it might be easier to get such an Institute started and sold to the other industries by making use of the present organization and facilities of the Ceramic Society.

Any tests desired would be asked for by the Clay Products Institute. The representatives of the various industries within the Institute would, of course, supervise all tests as at present, but the results would be published with the prestige of the Clay Products Institute behind them.

Not only technical data, but non-technical information of interest to the average man might be issued by the Institute also.

The entire cost for the first year should not exceed $7,500 to $10,000; and this overhead should be borne by the Associations supporting the Institute. The cost of any testing work would be paid for by the Association or the member who ordered such work done—exactly as is the case at present.

The second proposal, entirely distinct from the first, is this:

Mr. Stoddard and Mr. Bowen, in going around the country, have found that there is a distinct need for some testing laboratory, where clays can be tested. If a manu-

[1] From report of Proceedings of Sixth Annual Convention.

facturer is not entirely satisfied with the product he is getting from his clay, he wants to know why; or, if his clay bank is exhausted and he wants to continue in business in the same locality, naturally he wants to locate some other source of supply of his material.

It seems that there is quite a strong demand for a laboratory of this kind, and I am very pleased to offer to you this suggestion for the running of a laboratory now established.

Proposal for the Running of an Experimental Brick Plant

There is a practical stiff mud brick plant now lying idle in one of the buildings at Ohio State University at Columbus, designed by Col. Orton.

It is proposed that the U. S. Bureau of Mines, Ohio State University and this Association coöperate and run this plant to test clay in a practical manner.

Plant Cost: The plant cost originally about $11,250. It never has been run. It would need a little changing and additional equipment to put into actual operation. The University would pay part of such additional cost and we would pay part. Our part is estimated by Mr. Bole, Supt. of the Ceramic Station of the Bureau, at $2250.

Operating Cost: Cost of operation would be borne partly by us and partly by Bureau of Mines. Based on full time operation of plant (about 12 to 14 kilns per year) this would be about as follows. (Bureau of Mines estimate.)

	Our expenses	Bureau and University expenses
Fuel	$1000.00	
Repairs and Upkeep	1000.00	
Cartage of clay	1200.00	
Power, light and heat		$ 650.00
Superintendent, at $3500	1000.00	2500.00
Junior engineer		1800.00
Labor	1500.00	
	$5700.00	$4950.00

In addition, all overhead is borne by U. S. Bureau of Mines.

Ceramic Experts Available: The entire facilities of the Bureau of Mines Experiment Station and the Ceramic Department of Ohio State University would be available for consultation without charge. Personnel includes ceramic engineer, chemists and petrographer. Bureau has complete ceramic laboratories fully equipped.

MR. SIMONS: I want to lay this before the members and directors for consideration. It is in reference to raising funds to continue the activity of your national association, and take up just such things as have just been presented, and I would like you to take it into consideration. I don't ask for any action at this convention, but I would like to have you think about it.

We find that we are getting great returns in this state and expect, from the amount of money we are putting into it, and hope, that we will have demonstrated in the course of a year or so, that we can even grow double the amount.

The law of compensation is that you only get out what you put in. You have to give in order to get, so under that policy, we are satisfied here, and I wish the members of this organization would consider it possibly at another meeting, or the board of directors would take it under consideration, and ask for a referendum on it, to the members, so that we might get action.

I don't believe that the Association should go into any proposition where we sustain a laboratory at this time, because we are short of funds. If men want to have their clays examined or anything of that kind they should be willing to pay for it.

There are too many men going into the brick business who are not qualified to be in. They should learn something first. A good way is to get up early and go out to the plant and work hard. Don't believe a lot of things a lot of promoters who come along try to tell you what clay will do. It isn't so hard, if you are a little bit patient and go down to the foundation of the business and work along with it, to find out for yourselves.

MR. F. T. HOULAHAN: (Seattle, Wash.) If I may I would like to differ with my good friend, Mr. Simons. I think I have a good reason to differ with him. Not so very long ago our association mailed out to the different members and the other trade associations did the same thing, a report of a committee of some sort or other, that went into the burning problem. We got this report because of our membership in the association.

We have reduced our burning time and saved money in burning, and I would like to make a motion at this time that this association go on record as favoring coöperation with the Bureau of Mines.

MR. SCHLAKE: I am not going to oppose that motion, although I am not satisfied in my mind that we are right to go along with it or as favoring something that might require the expenditure of a considerable sum of money. I believe that any undertaking along those lines is going to pay when the proper time comes. I would suggest that instead of taking action here, where it is going to be impossible to weigh all the arguments pro and con, that the matter be referred to the Board of Directors. I have no objection to coupling this up as an amendment to the motion that the convention feels that this subject is well worthy of consideration, and hope for favorable action.

MR. HOULAHAN: Under those circumstances I will withdraw my motion. I think probably it is better that the board should act on it, but I feel very deeply on this subject. We have a Bureau at the University of Washington and it has done all the clay workers around that section a lot of good where we have taken advantage of it, and I think wherever the clay worker can work in harmony with the technical man he should do so. Understand, I am not a technical man, and up until a year or two ago I thought a technical man was the "bunk"—but there is merit in them; some of them at least, and they have good horse sense. They are doing mighty fine work and I am for that right down the line.

MR. STEPHENSON: Last year a communication came to my plant. One of my boys is in charge of it, and he hadn't very much experience in burning brick and did not have that to do—he was in general charge of the plant, that was all. This came from the Common Brick Association, and was a partial report from the Bureau of Standards on burning. The boy read that over and he immediately saw that someone had been thinking; someone besides a theoretical man, someone who had gone to the bottom of it. He read it over again and then he took it out to his head burner. He said, "I wish you would read that over, at your leisure, and when you get through, read it over again, and let me know what you think about it."

The burner came back a little later and said, "It won't do. There is nothing to it It is too dangerous to fool with." He said, "I have burned brick in just about that same length of time, but five days, or five and a half days—you can't do it, and make a regular practice of it." When asked why, he said, "A man couldn't stand it, he'd have to be right on the job every minute of the time. I wouldn't have anything to do with it."

"All right," said my boy, "I am going to take that and burn a kiln myself according to that paper."

He took charge of it and burned the kiln off in about five days and four hours. We had been burning an average of eight and a half to nine days, and since that time we have adopted the plan entirely. We followed out the suggestions to the letter, and we

have cut our burning time down to anywhere between five and five and a half days. Before we tried that we didn't have kiln room enough, and now we have kilns standing idle. We have reduced the amount of fuel and labor also, and I would say that we are saving enough on this one investigation of the Bureau of Mines through the coöperation of the Common Brick Manufacturers Association for me to contribute a fellowship to the Bureau of Mines individually, but I feel like Andrew Gump. He lost all his money in the hairbrush and mirror business and as soon as it came back to him he told them immediately, "I knew I could arrange some way to get it back."

I am not wanting to give what I have already gained by this information, I am wanting more information. I am willing to start over again and contribute with the association.

CERAMIC STUDENTS WIN FIRST PRIZE IN THE UNIVERSITY OF WASHINGTON ENGINEERS' OPEN HOUSE

The ceramic engineering students, College of Mines, University of Washington (Seattle) competed with the departments of Civil Engineering, Mechanical, Chemical, Forestry, Fishery and Electrical Engineering and walked off with the first prize. Exhibitions were made of the manufacture of brick and tile; pottery by the hand throwing, casting and jiggering methods; glass tumblers; spraying and firing of terra cotta; purification and filter pressing of Eastern Washington kaolins; manufacture and testing of super-refractories and enameled metals. Over 200 two-inch brown and white jugs made by the students together with 50 colored vases were given out as souvenirs. The Engineers' Open House is given every two years at the University of Washington and has quite a reputation for high class exhibitions. Several thousand people visited the department on Friday and Saturday, April 11th and 12th.

CALENDAR OF CONVENTIONS

Organization	Date	Place
AMERICAN CERAMIC SOCIETY (Summer Meeting)	July 21–Aug. 1924	Trip to Pacific Coast
AMERICAN CERAMIC SOCIETY (Annual Meeting)	Feb. 16–21, 1925	Columbus, Ohio
Am. Foundrymen's Assn.	Oct., 1924	
Am. Gas Assn. Inc.	Oct., 1924	
Am. Iron and Steel Institute	May 23, 1924	New York
British Assn. for the Advancement of Science	Aug. 6–13, 1924	Toronto, Canada
Chamber of Commerce of the U. S. A.	May 6–8, 1924	Cleveland, Ohio
Chemical Equipment Assn.	Sept., 1924	
Colloid Symposium	June 19–21, 1924	Northwestern University, Evanston, Ill.
Eastern Paving Brick Mfrs. Assn.	Dec. 9, 1924	New York (?)
Manufacturing Chemist's Assn.	June, 1924	New York
Natl. Assn. of Mfrs. of U. S. A.	May 19–21, 1924	New York
Natl. Assn. of Stove Mfrs.	May 14–15, 1924	New York, Hotel Astor
Natl. Bottle Mfrs. Assn.	Last Wk. Apr., 1924	Atlantic City

Organization	Date	Place
Natl. Glass Distributor's Assn.	Dec., 1924	Pittsburgh
Natl. Lime Assn.	May 20–23, 1924	White Sulphur Springs, W. Va.
Natl. Ornamental Glass Mfrs. Assn. of U. S. and Canada	June 24–26, 1924	New York
Natl. Paving Brick Mfrs. Assn.	Dec., 1924	
Society of Promotion Engineering Education	July, 1924	Boulder, Colo.
Stoker Mfrs. Assn.	May or June, 1924	
U. S. Potters Assn.	Dec., 1924	Washington, D. C. (?)
Western Glass and Pottery Assn.	June 15, 1924	Pittsburgh
Western Society of Engineers	June 4, 1924	Chicago

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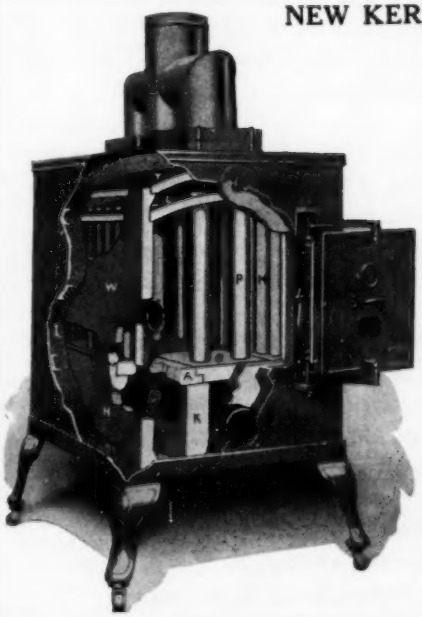

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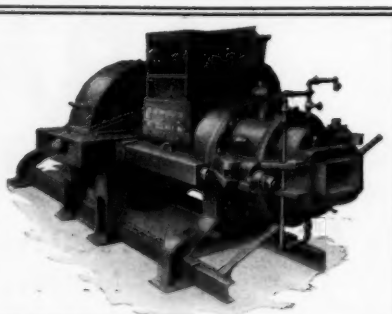

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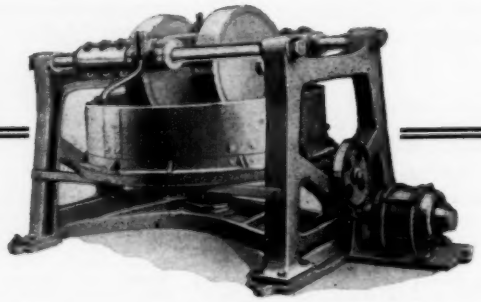

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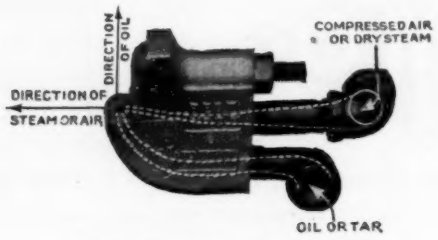

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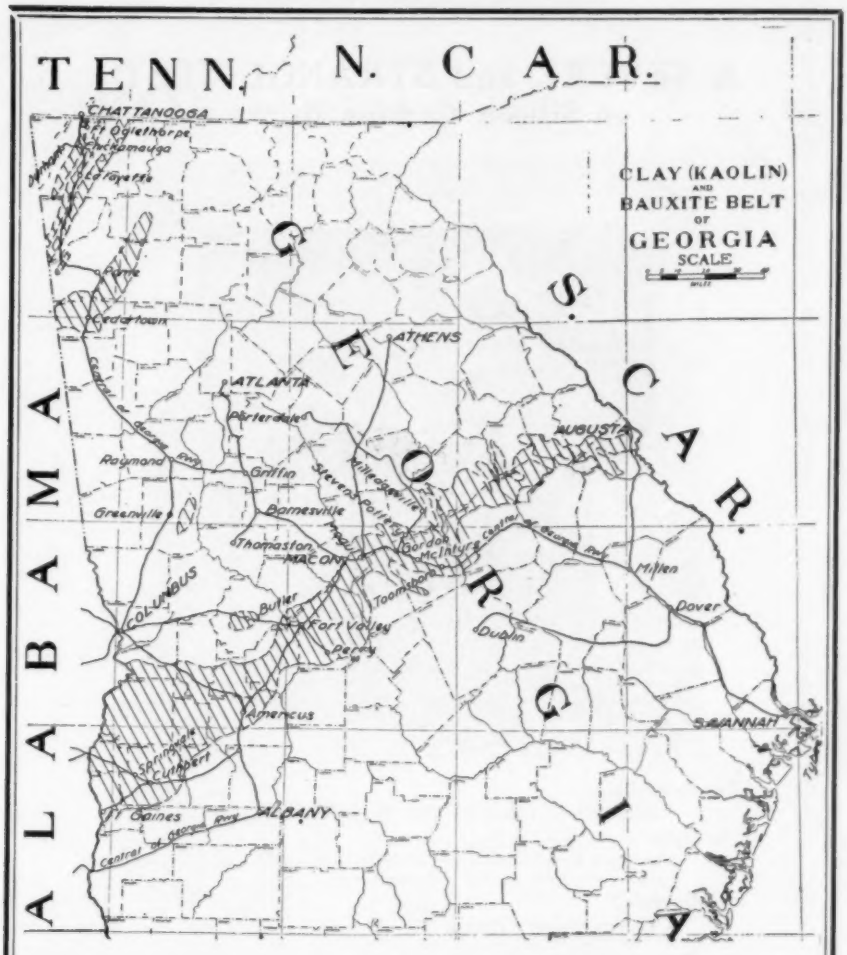

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